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DEVELOPMENT OF 20mm PLASTIC/ALUMINUM CARTRIDGE CASE

AAI CORPORATION

TECHNICAL REPORT AFATL-TR-74-62

MARCH 1974

AIR FORCE ARMAMENT LABORATORY

AIR FORCE SYSTEMS COMMAND • UNITED STATES AIR FORCE

EGLIN AIR FORCE BASE, FLORIDA

Development Of 20mm Plastic/Aluminum Cartridge Case

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FOREWORD

This report documents work on the 20mm Plastic/Aluminum Cartridge Case performed during the period 19 April 1973 to 28 February 1974 by AAI Corporation, Cockeysville, Maryland, 21030, under Contract F08635-73-C-0102 with the Air Force Armament Laboratory, Eglin Air Force Base, Florida. The Project Engineer for the Armament Laboratory was Major Stephen J. Bilsbury (DLDG).

The report has been assigned AAI Corporation Engineering Report Number ER-7792.

This technical report has been reviewed and is approved.

DALE M. DAVIS
Director, Guns and Rockets Division

ABSTRACT

The goals of this program were to arrive at a final design for the 20mm plastic/aluminum cartridge case by: (1) studying and eliminating, if possible, the case cracking problems encountered during temperature extreme firings; (2) improving case resistance to rough handling; and (3) establishing molding process parameters for high volume production. The basic case consists of a plastic body joined mechanically to an aluminum base forming a composite assembly. The existing plastic/aluminum case design was used as a basis, and modifications were made to it as judged necessary. Each modification was followed by test firing to verify and record any changes in performance and case integrity. Test firings were performed with a Mann barrel and with the M61 automatic gun firing at a rate of 4,300 rounds per minute. General results were that temperature extreme firings continued to present problems relating to case integrity. Numerous case modifications with accompanying firing data have served to isolate various failure modes and have led to a better understanding of certain failure occurrences. Further development will be necessary to apply the accumulated knowledge to reduce and subsequently eliminate all case failures. During this program, molding process parameters for high volume production as well as a production mold design have been established. A complete drawing package for the production mold was prepared and is included as Appendix II to this report. In addition, an alternate method of assembling the plastic body and aluminum base was investigated and proven feasible by firing tests. This method consisted of joining the components with a unique bonding process in place of the expensive mechanical joint previously employed.

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SECTION I

INTRODUCTION

This program was essentially a continuation of the work conducted previously in which basic feasibility for the 20mm plastic/aluminum cartridge case was established. At the conclusion of the original effort, some problems in case integrity remained and demanded further study. This program, therefore, was an effort to eliminate case failures which occurred occasionally during firings at high and low temperature extremes. Additional work on this program included: the design of a simulated production mold; establishment of molding process parameters; effort to improve rough-handling characteristics; set-up of a complete inspection station utilizing air gages; establishment of case dimensions and tolerances; and manufacture and delivery of a quantity of cartridge cases.

Included in this report is a description of the 20mm plastic/aluminum cartridge case, explanation of test methods, a narrative describing development testing, conclusions, and recommendations, and appendices which contain drawings of the test and production molds and case component details.

SECTION II

DESIGN DESCRIPTION

1. PHYSICAL DESCRIPTION

The 20mm cartridge case is a three-piece composite consisting of a plastic body, an aluminum base, and an internal rubber seal. The plastic body and the aluminum base are mechanically joined by mating buttress-shaped teeth which snap into place when the body is pressed into the base. The plastic body extends inside the base and insulates the thin-walled aluminum section containing the buttresses from contact with the hot propellant gases. The rubber seal insulates the lower portion of the base not covered by plastic and also provides a seal at the body/base interface. Figure 1 shows two 20mm plastic/aluminum cases. One is cut away to show the internal configuration.

The 20mm case joint contains two buttresses for mechanically joining the plastic body and the aluminum base. The molded buttresses of the plastic body are a press fit of about 0.005 inch on the diameter with the corresponding surfaces in the base. At assembly, the plastic body is pressed into the base and the teeth snap into place. The fit on the plastic provides a firm joint that resists rotational slippage and forms a watertight seal. On firing, the plastic inside the aluminum base obturates by internal gas pressure against the base, thus sealing the joint area from gas leakage. The joint design allows some relative movement between the two parts in a lengthwise direction. If a longitudinal compressive force is applied to the case, there will be some rearward movement of the plastic body inside the aluminum base. The case is made approximately 0.045 inch longer than standard from the shoulder to the base so that at chambering the case will be compressed and shortened by that amount. At firing, the bolt deflection that occurs at peak pressure can then be taken up by that amount of compression before any tensile loads are applied to the joint area. This serves to reduce the stress levels in the case that may occur from axial tension caused by bolt deflection and decreases the possibility of failure at the joint.

The base of the cartridge case is subjected to the most severe internal stresses of any part of the case. The extractor groove area is unsupported by the chamber and must withstand the stresses caused by internal gas pressure. Tests have shown 7075-T6 aluminum alloy to be the material best suited for this purpose since it has the required mechanical properties to withstand the high stresses imposed at firing. In addition, the low density of aluminum makes it attractive from a weight standpoint. A detail print of the cartridge base, AAI Drawing No. 53593-40001, is presented in Appendix I of this report.

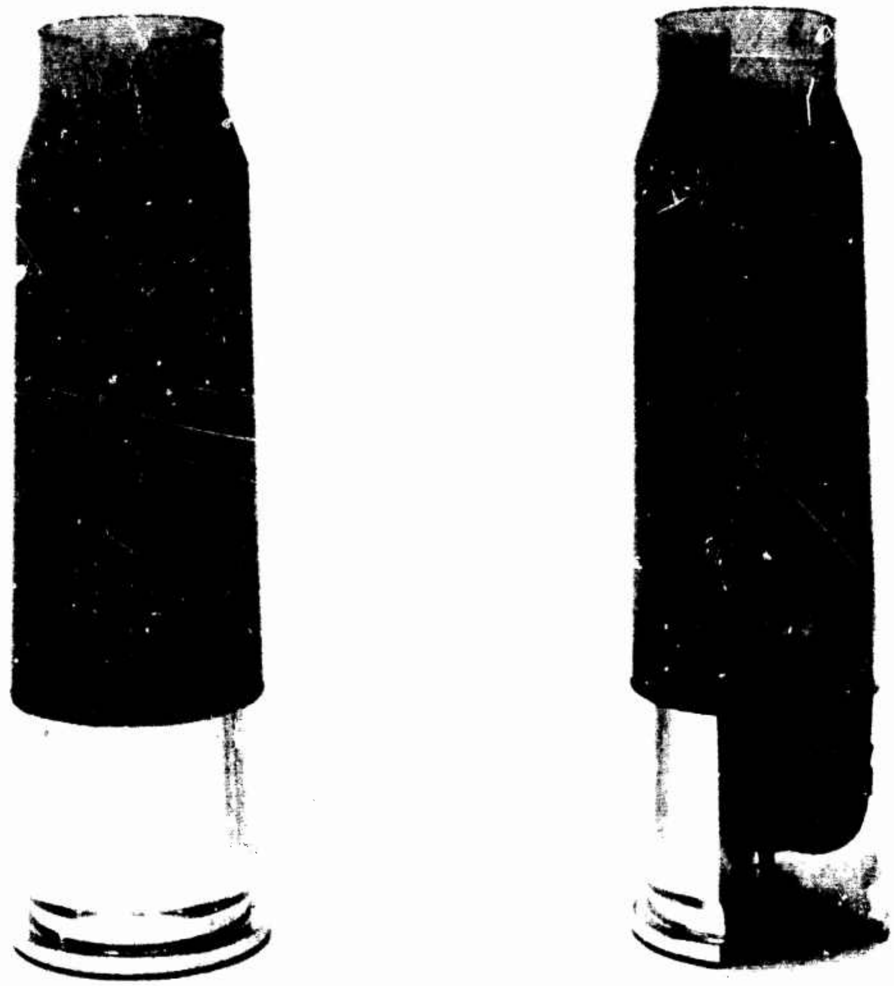

Figure 1. 20mm Plastic/Aluminum Cartridge Case

The base contains two buttresses corresponding to those on the plastic body for mechanically locking the two components. The thin walls of the base expand outward at firing to contact the chamber. The outside dimensions are such that a line-to-line contact with the chamber will exist at the minimum chamber and maximum base size tolerances. At the opposite dimensional tolerances, maximum chamber and minimum base, a clearance of 0.004 inch on the diameter exists. The material elongation is sufficient to permit base expansion at firing to contact the chamber walls.

The base will accept the standard M52A3B1 electric primer used in the M103 brass cartridge case.

To prevent corrosion, a chemical film coating per MIL-C-5541 is recommended for the aluminum base. It is a good electrical conductor so that the operation of the electric primer will not be impaired. The chemical film coating can be dyed any color should color coding of the munition be desired.

The rubber seal is a molded component of silicone rubber[1] which fits the internal configuration of the base with an opening at the primer flash hole. It serves to insulate the aluminum, thereby minimizing the chances of an aluminum burn-through. The seal is inserted into the plastic body prior to assembly with the base, and after assembly it is pushed down against the bottom of the case. A detail drawing of the seal, AAI Drawing No. 53593-40014, is presented in Appendix I.

The plastic body is an injection molded part of glass-reinforced nylon. The formulation consists of type 12 nylon resin[2] mixed with 0.25-inch-long glass fibers to the amount of 50 percent by weight of the total mix. The material is marketed by LNP Corporation, Malvern, Pennsylvania. The base resin is obtained through Mobay Chemical Company, East Brunswick, New Jersey, from Huls of West Germany. LNP mixes the base resin with the desired glass loading.

The outer dimensions on the plastic body provide a line-to-line contact with the chamber at minimum chamber and maximum case tolerances and a 0.004-inch clearance on the diameter at the opposite extremes. The joint area diameter is molded about 0.005-inch oversize to provide for a tight fit with the base in order to prevent rotational slippage and to effect a watertight seal.

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1 Dow Corning Silastic Base No. 433

2 Huls resin No. L-1801

Projectile retention is accomplished with a continuous, circumferential bead that is molded into the inside surface of the case neck. The bead mates with the crimp groove in the M55A2 projectile. The projectile is assembled into the case neck by a pressing operation which is performed on a standard arbor press. The projectile is inserted into the plastic case neck and is aligned visually to preclude cocking during the pressing operation. The projectile is then pressed into the case allowing the bead in the case to ride over the rear of the projectile and snap into the crimp groove. The elongation property of the plastic coupled with the fact that the case neck is not supported externally for this operation, allows the neck to expand radially without cracking to provide passage of the rear of the projectile. At firing, with the neck supported radially by the chamber, the bead is sheared out by the projectile. A force of 200 pounds is required to shear the bead with the neck supported radially. A detail drawing of the plastic body, AAI Drawing No. 53593-40002, is presented in Appendix I.

The assembled munition contains 37.0 grams of WC 870 double-base propellant manufactured by Olin Mathieson. The total available case volume is 2.38 cubic inches. The munition component weights are:

Plastic/Aluminum Case (with seal)	39.3 grams	0.0866 lb
WC 870 Propellant	37.0 grams	0.0816 lb
M55A2 Projectile	99.0 grams	0.2183 lb
	175.3 grams	0.3865 lb

Figure 2 shows the assembled 20mm plastic/aluminum case munition.

2. PERFORMANCE

The propellant charge weight of 37.0 grams of WC 870 double-base propellant loaded in the plastic/aluminum case provided performance comparable to the M103 case which is loaded to a charge weight of 39 to 40 grams. All firings were performed with the M55A2 projectile. The following are average velocities and pressures of both cartridge cases averaged from the results of Mann barrel firings.

	Velocity	Peak Pressure
Plastic/Aluminum	3350 fps	47,500 psi
M103 Brass	3350 fps	51,000 psi

Presented in Section IV of this report are pressure versus time traces obtained from firing tests of the plastic/aluminum case.

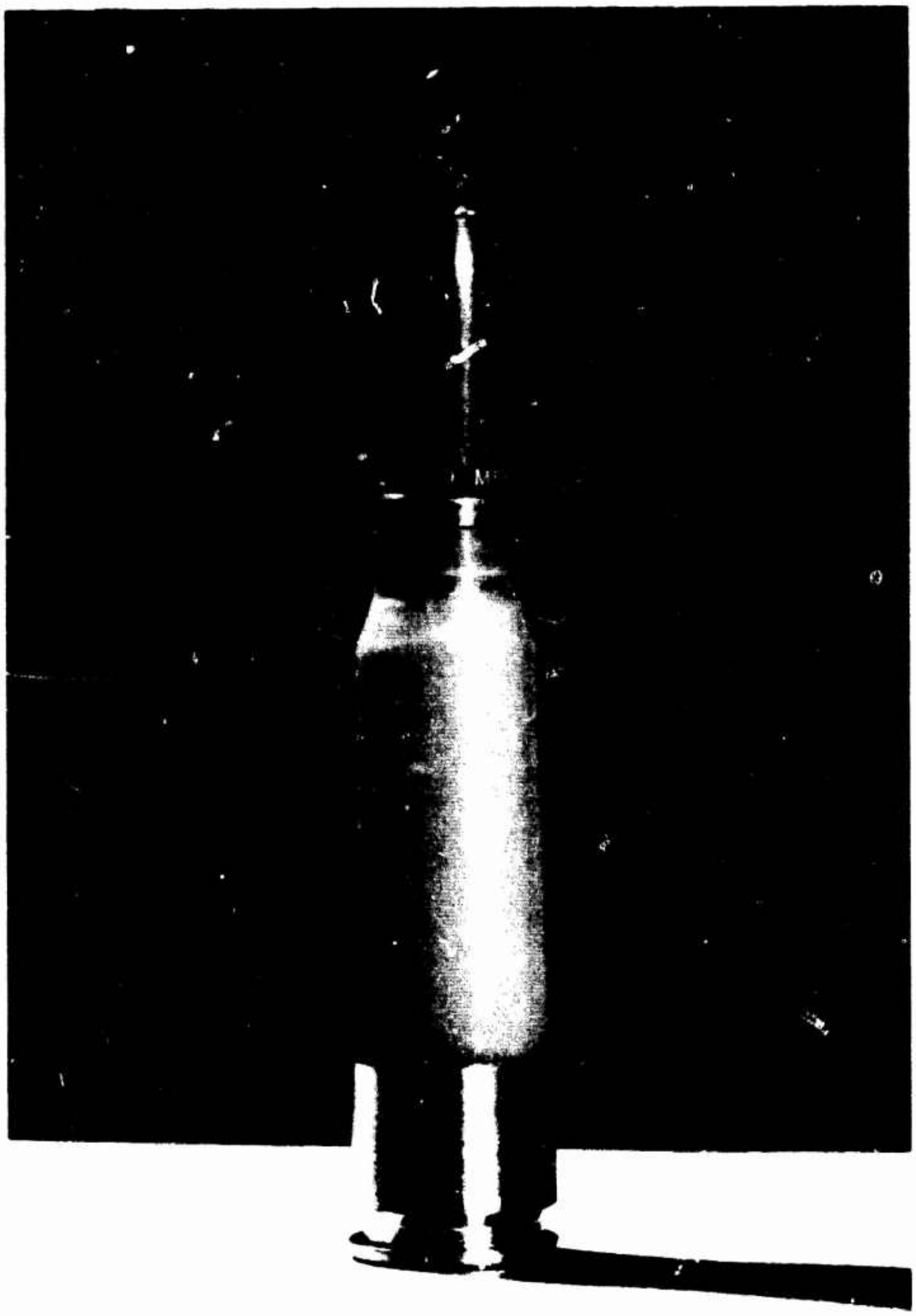


Figure 2. 20mm Plastic/Aluminum Case Munition

SECTION III

TEST METHODS

1. VELOCITY MEASUREMENT

The projectile velocity was measured using counter chronographs in conjunction with light-sensitive velocity screens. The velocity screen consists of a tungsten lumi-line tube light source which shines directly across the projectile line of flight to a photoelectric tube. As the projectile passes through the screen, its shadow is cast on the photoelectric tube which then sends out an electrical pulse. The electrical pulse is used to trigger or to stop a counter chronograph. With the start and stop screens set at a known distance apart, the recorded time to travel that distance will yield the average velocity between screens. For these tests, two sets of velocity-recording apparatus were used. The redundant set-up was arranged with the start and stop screen pairs 10 feet apart, with the first start screen being 20 feet from the muzzle and the second start screen 34 feet from the muzzle. The two readings were averaged.

2. PRESSURE MEASUREMENT

To obtain pressure versus time traces, a small hole was drilled in the case wall corresponding in location to a port in the Mann barrel chamber. At firing, the gas pressure acts against a piston inserted in the chamber port which, in turn, transmits the force to a quartz dynamic force transducer. The transducer sends an electrical pulse which is then read out on an oscilloscope and subsequently recorded on a Polaroid photograph. The resulting photograph is a pressure versus time trace.

3. TEMPERATURE EXTREME TESTS

The 20mm case was tested at temperature extremes by conditioning the loaded ammunition separately for a minimum of 4 hours at the desired temperature. All cases were tested after being stored under ambient conditions for at least 24 hours after molding. For cold tests ($-65^{\circ}F$), a cold chamber operating with liquid CO_2 was utilized. For hot tests ($165^{\circ}F$), an electrically heated chamber was used. Both environmental chambers were equipped with automatic temperature controls. When ready for firing, the rounds were transported to the test site in insulated containers, loaded in the M61, and quickly fired to minimize any temperature change. Elapsed time with the rounds in the container was about 2 minutes. Time to load the rounds from the container into the gun and fire was about 10 seconds.

SECTION IV

DEVELOPMENTAL TESTING

The basic design for the 20mm plastic/aluminum case was established under Contract No. F08635-70-C-0067. The work to be accomplished under this contract was to establish a compatible mold/case design suitable for production injection molding techniques and to make improvements in the design to alleviate problems experienced during previous testing. The two major considerations were elimination or substantial reduction of flow lines (believed to be the cause of occasional longitudinal cracks during cold tests) and modification of the neck area to eliminate drop test failures.

1. CASE DEVELOPMENT

A total of thirty-six different case designs and eight different materials were tested during this program. Five basic case configurations were evaluated with minor physical, dimensional and molding variations being made to each. Table I shows these basic designs and lists the changes by case type. The plastic materials considered were selected based on satisfactory performance during the last contract or were specially formulated by DuPont to meet the mechanical and chemical requirements for the plastic case. As Huls 12 nylon/50 percent glass-impregnated appeared to be the most suitable case material, according to test results from the previous contract, it was used as the base line for evaluating new materials. Huls 12 nylon/50 percent glass-impregnated, used during most of the case design tests, was selected at the end of the contract as the basis for design since none of the other materials tested performed as well. The only change was the Huls 12 initially used was the Thermofil version while the final material was the LNP version.

a. Case Configuration A

The first case configuration (see Figure 3) to be designed (designated type 2) and tested was essentially the same as the case at the close of the previous contract. The only change was the addition of a thick molded collar to the inside of the case in the area of the neck just aft of the projectile. It was believed that this collar would strengthen the neck and provide support for the projectile. The added support was necessary to prevent splitting of the thin wall neck during drop tests. The support collar accomplished this during nose-down and base-down drop tests but failed to strengthen the neck sufficiently for successful lateral drops. By its configuration, the M55 projectile has a ratio of unsupported to supported length of nearly seven to one. Because of this, the neck experiences a large bending moment in a lateral drop, causing the thin wall to fail in the form of a longitudinal split.

The gating system was also revised. The original four feed gate [feeding the neck from the forward end (see Figure 4)] was deleted, and a diaphragm internal gate feeding the new collar (see Figure 5) was added.

TABLE I. DESCRIPTION OF CASE CHANGES

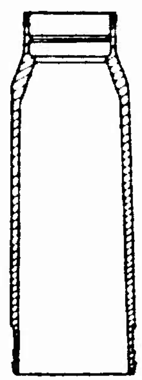
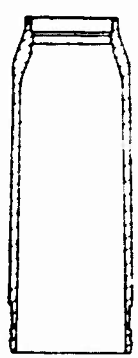
Case Configuration	Case Type No.	Description of Change	Reason for Change	Results
 A	2	Case with internal molded collar-diaphragm gate 1st new design	Eliminate flow lines and support projectile for drop test.	Flow lines eliminated but did not pass drop test; however, neck separation occurred when fired.
	3	Case same as type 2 except neck O.D. increased by 0.004	Eliminate neck separations	Not successful
	8	Gate increased from 0.030 to 0.060	Eliminate neck separations	Neck separations eliminated under ambient conditions but did not pass drop tests.
 B	4	Case same as type 3 except neck machined off and collar machined out to neck I.D. -0.030	Pass drop test	Drop test passed but cases failed at the base/case joint.
	5	Same as type 4 except neck removed to retaining bead	Pass drop test without losing as much internal volume as #4	Neck separations
	6	Same as type 1 except neck removed to retaining bead	Eliminate neck separations	Not successful
	7	Same as type 5 except collar machined into 0.120 wide bead	Eliminate neck separations	Not successful

TABLE I. DESCRIPTION OF CASE CHANGES (Continued)

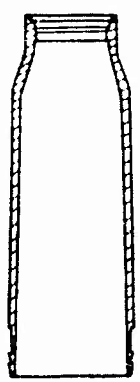
Case Configuration	Case Type No.	Description of Change	Reason for Change	Results
 C	10	Neck wall thickness increased from 0.030 to 0.070 wide bead molded in	Eliminate neck separations and pass drop test	Drop test passed but neck separations continued.
	11	Same as type 10 except neck is stepped	Eliminate neck separations	Not successful
	12	Same as type 11 except bead length reduced to 0.060	Eliminate neck separations	Not successful
	13	Same as type 11 except O.D. of neck turned down to 0.835	Eliminate neck separations	Successful at -65°F
	14	Same as type 11 except O.D. reduced by 0.005 (molded)	Additional tests of type 13 except molded instead of machined	Neck separations at +165°F
	15	Base I.D. increased by 0.006	Eliminate base/case joint failure	Not successful
	16	Same as type 14 except projectile retaining bead machined out	Eliminate neck separations	Not successful
	17	Same as type 16 except O.D. of neck reduced 0.004	Eliminate neck separations	Not successful
	18	Same as type 15 except shoulder wall is 0.030 thick	Eliminate neck separations	Not successful
	19	Same as type 15 except shoulder wall is 0.70 thick	Eliminate neck separations	Not successful
	20	Same as type 15 except neck wall is 0.045 thick (Machined)	Eliminate neck separations	Not successful

TABLE I. DESCRIPTION OF CASE CHANGES (Continued)

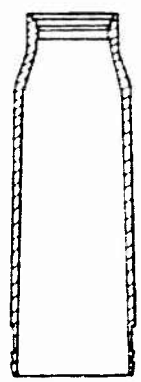
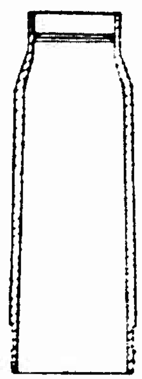
Case Configuration	Case Type No.	Description of Change	Reason for Change	Results
 D	21	Cases from production (new) mold and bases from production run	Increase strength of plastic material and provide better fit in chamber to eliminate all failures	Neck separation and case failures still occurred mainly at +165°F
	22	Same as type 21 except I.D. of step is tapered	Eliminate neck separation	Not successful
	23	Base lubricated	Eliminate base failures	Successful
	24	Base same as type 3 except 0°45' taper cut taken on rear of base	Eliminate base/case joint failures	Successful
	25	Same as type 21 except neck I.D. 0.045 thick (Machined)	Eliminate neck failures	Not successful
	26	Base stress relieved	Eliminate base failures	Successful
	27	Case and base lubricated	Eliminate base/case joint failures	Not successful
	28	Same as type 21 except chevrons on case cut back 0.015 Bases lubricated	Eliminate base/case joint failures	Not successful
	29	Cut 0.008 to 0.010 taken across rear of base and base lubricated	Eliminate base/case joint failures	Not successful
	30	0.020 shim on front of case. Base lubricated	Eliminate base/case joint failures	Successful
	31	0.030 shim on front of case. Base lubricated	Eliminate base/case joint failures	Successful

TABLE I. DESCRIPTION OF CASE CHANGES (Continued)

Case Configuration	Case Type No.	Description of Change	Reason for Change	Results
 E	32	Same as type 21 except neck fluted and base lubricated	Eliminate neck separation	Not successful
	33	Same as type 21 except case 0.010 longer (molded) and base lubricated	Eliminate base/case joint failures	Not successful
	34	Same as type 21 except case 0.030 longer (molded) and base stress relieved	Eliminate base/case joint failures	Successful
	35	Core modified to provide thin wall (type 1) neck and "V" retaining bead	Eliminate neck separation	Successful
	36	Gate opening increased	Strengthen plastic to eliminate all failures	Successful

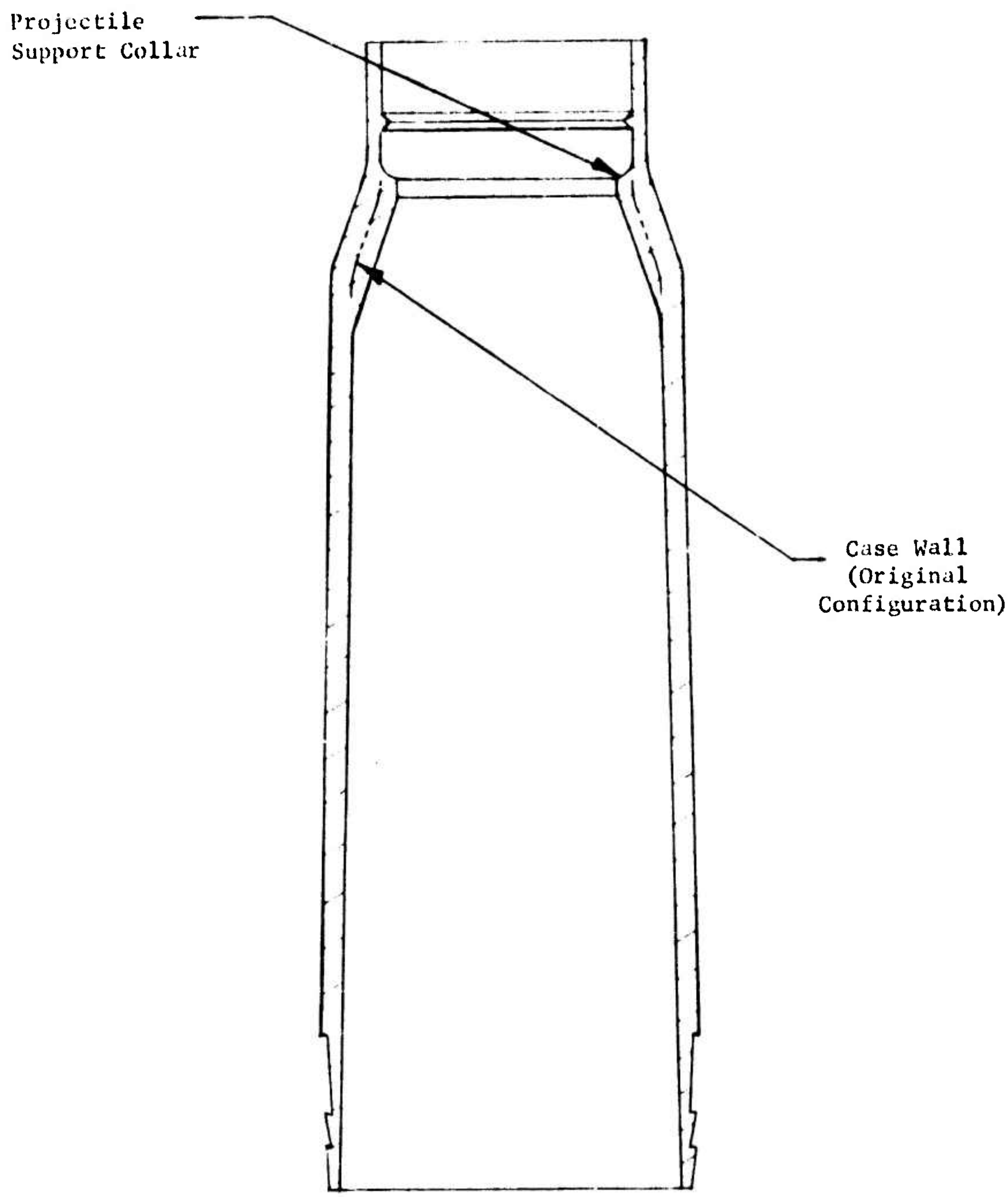


Figure 3. 20mm Plastic Cartridge Case
(Type 2)

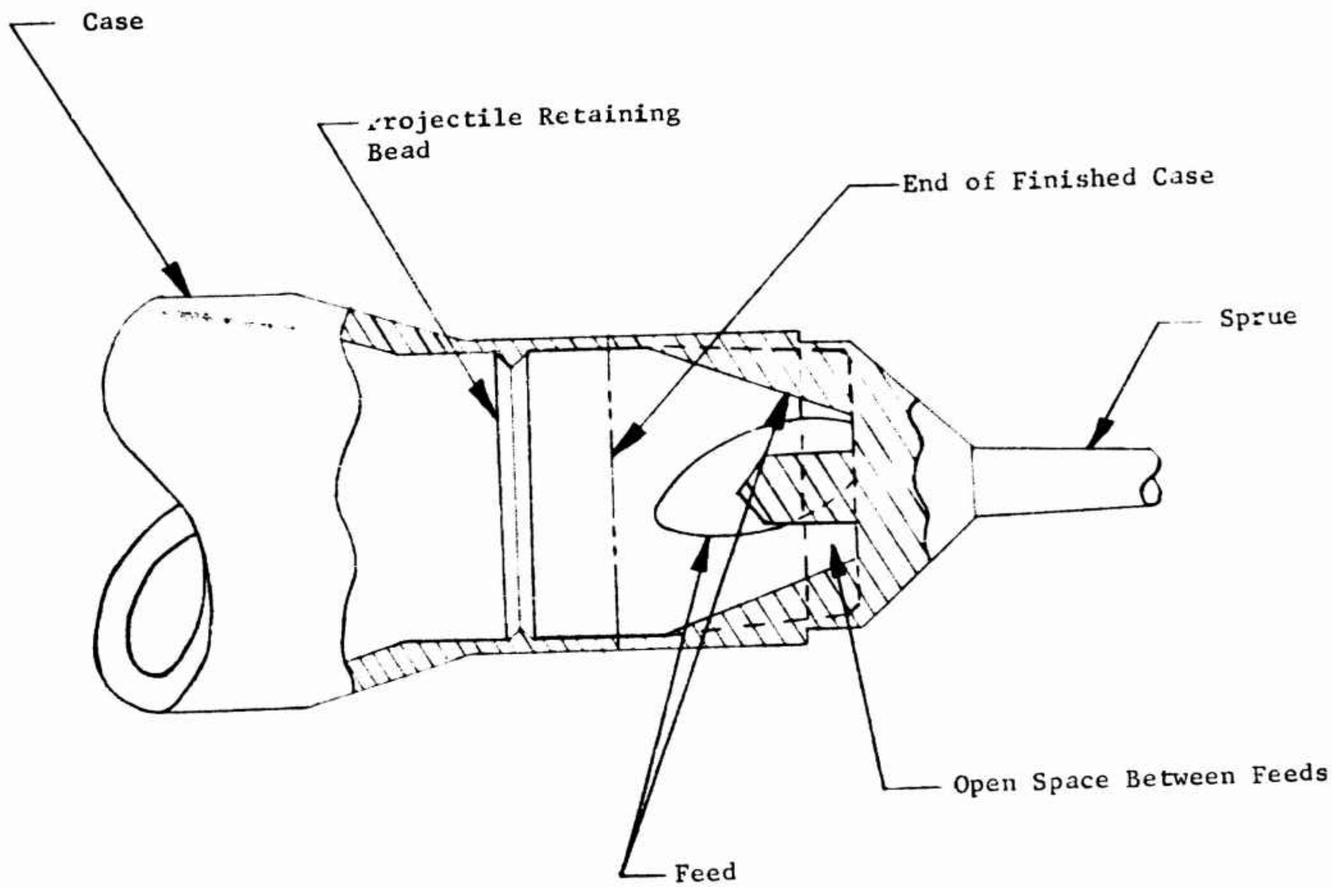


Figure 4. Four Feed Gate (Type 1 Case)

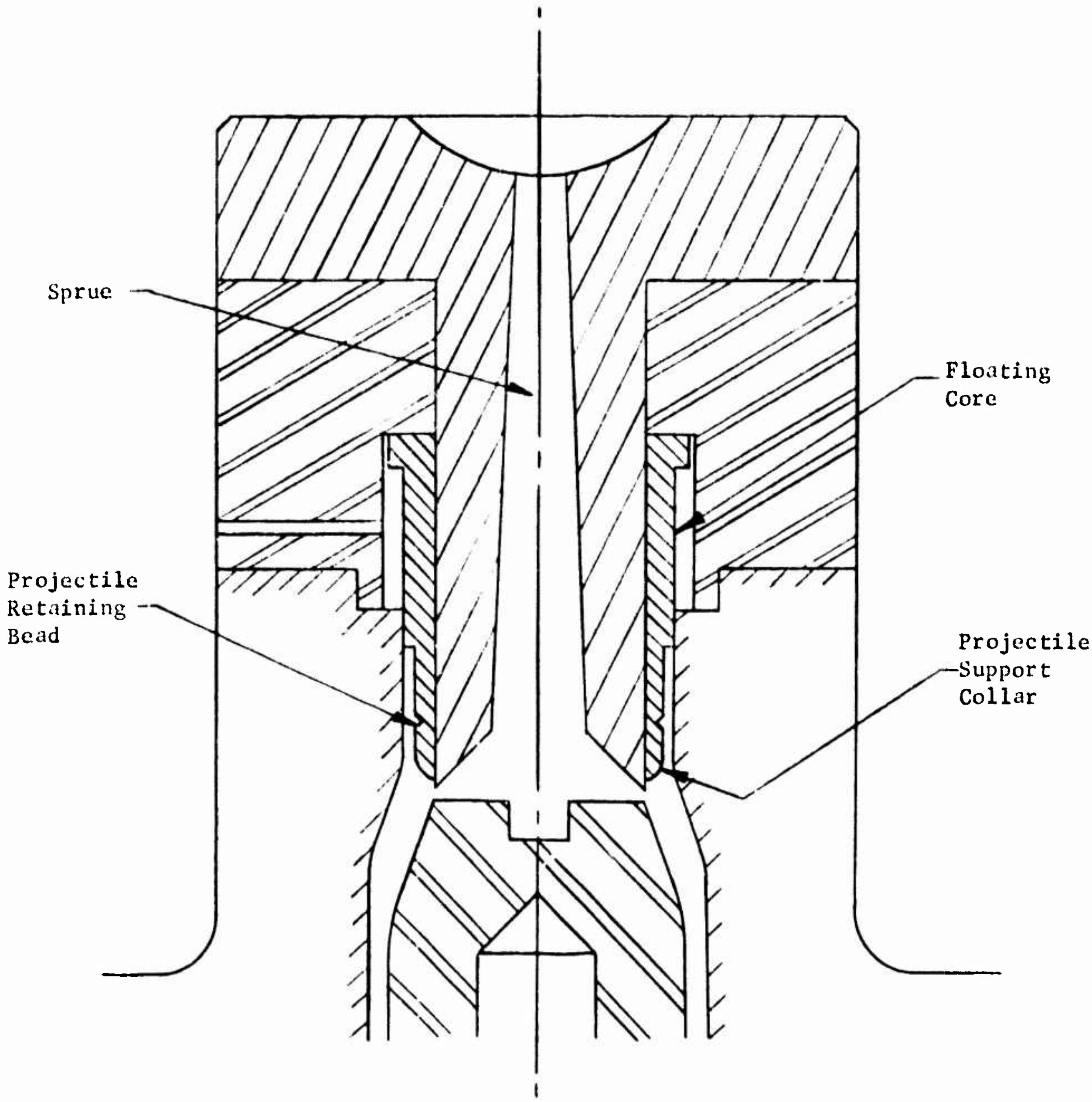


Figure 5. Floating Case Mold for Type 2 Case

This new gating method provided three desirable features. Since it fed directly into the collar, the case would fill from the thickest part, a desirable molding technique. The diaphragm form of gate virtually eliminated the flow lines. Although flow lines were present in some instances, they were faint and dissipated within one-third of a case length from the gate. An additional advantage of this type of gate is the fact that it can be easily punched out, leaving the finished case which is a desirable feature for facilitating production.

In the initial stages of the contract, another of the goals was to provide maximum velocity. To accomplish this, all of the type 2 cases tested were loaded with the maximum propellant charge they would accommodate (37.7 grams). This produced a velocity of 3,410 fps and a corresponding pressure of 55,000 psi.

These first cases exhibited a weakness in the area of the neck. Even when fired at ambient temperatures, the majority of the cases lost the necks (see Figure 6). This, coupled with neck failures during drop tests (previously described), necessitated a re-evaluation of the case design. There were only two apparent solutions to the neck failures: increase the thickness of the wall or eliminate the neck. Since the neck was as thick as possible without modifying projectile or the chamber, it was decided to shorten or eliminate the neck.

b. Case Configuration B

The new configuration round (type 7, see Figure 7) incorporated not only a shorter neck but also a revised projectile retaining bead. For test purposes, the new bead was machined out of the molded projectile support collar of a type 2 case. Due to the increased width it was possible to increase the bullet pull substantially (550 pounds for the new design versus 200 pounds for the original V-groove). In addition, the new bead nearly filled the retaining groove of the projectile and provided a more secure fit. Pressure and velocity tests were conducted. Due to space limitations the charge was 37.0 grams rather than 37.3 grams previously used. The resulting peak pressure at ambient temperature was 47,500 psi with a corresponding velocity of 3,325 fps. In testing this configuration, it was found that both the short neck and neckless versions passed the drop test, but the short neck case still lost the neck when fired through the M61 gun. It was believed that the neckless version of the case offered the best solution. Although the overall length of the round using this type of case was reduced by 0.68 inch, tests showed that it would still link, delink, and cycle through the M61 properly.

The design was reviewed, and it was determined that the loss of charge space and subsequent loss of velocity due to recessing the projectile was not acceptable. Alternative solutions to solving the drop test failures were suggested.

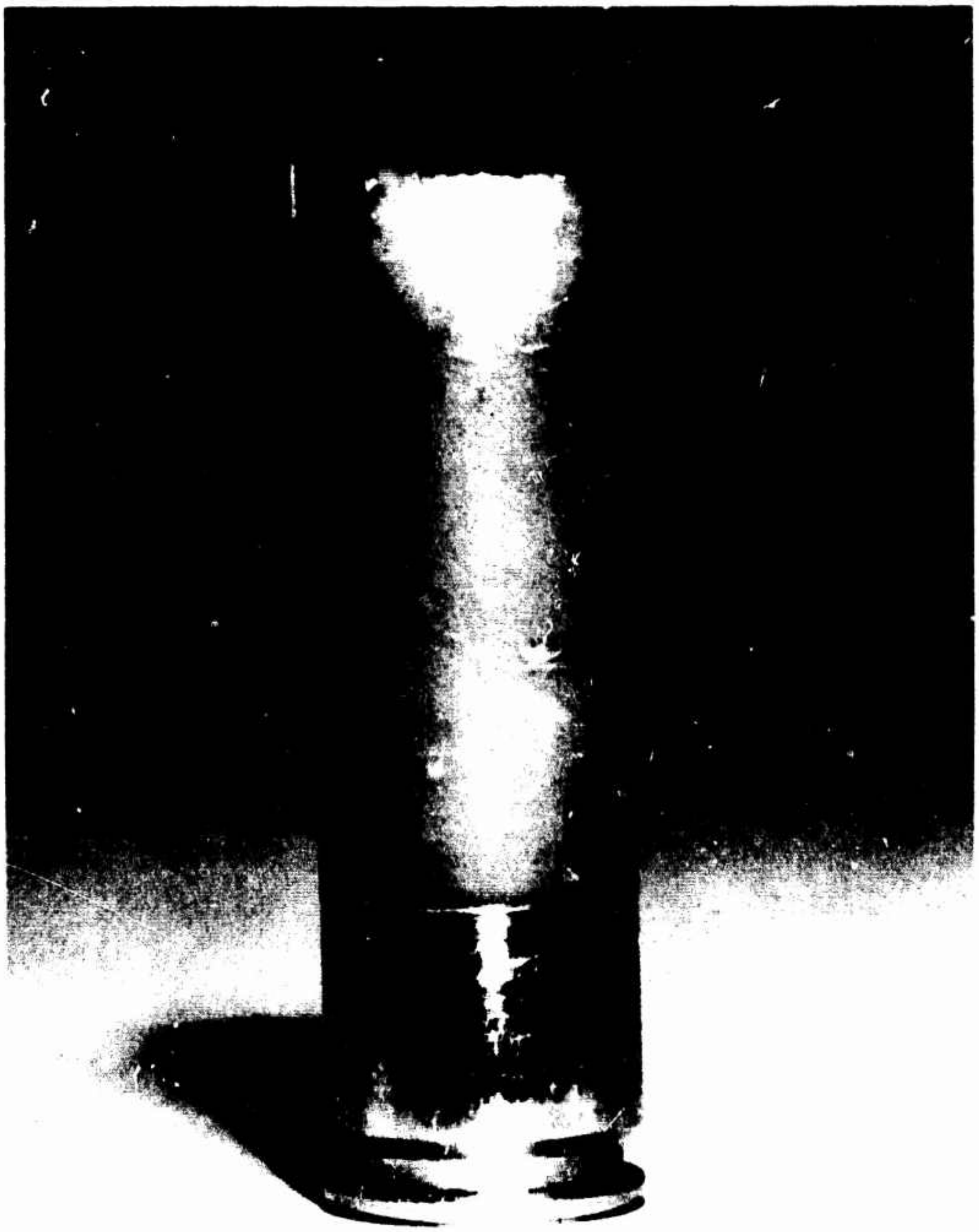


Figure 6. Typical Neck Failure

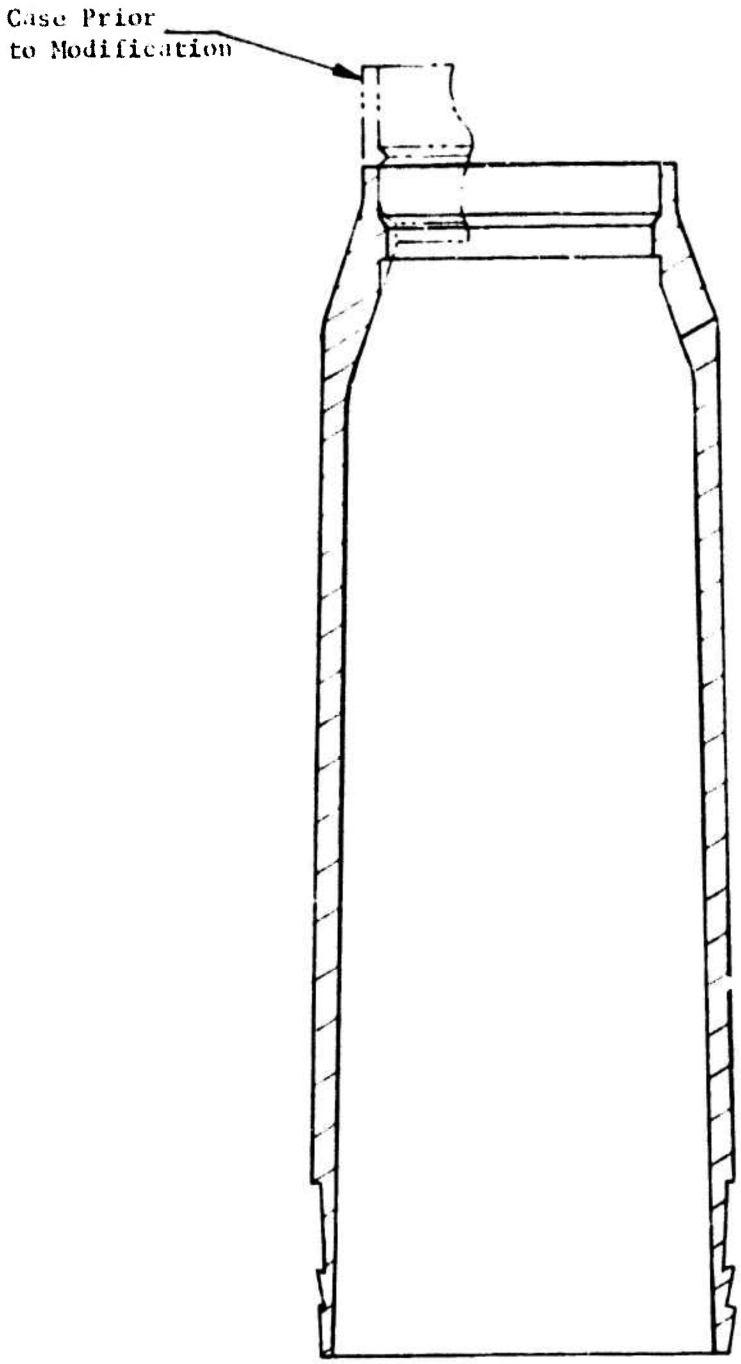


Figure 7. 20mm Plastic Cartridge Case (Short Neck Configuration)

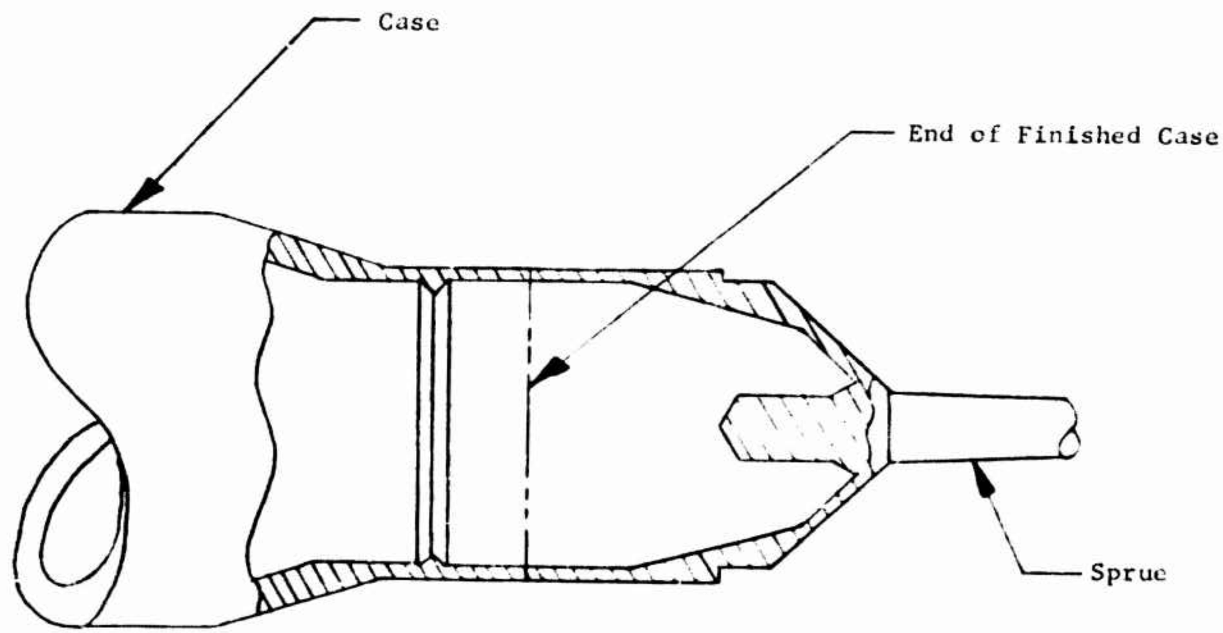


Figure 8. Diaphragm Gate (Case Type 9, 35, 36)

The internal projectile support collar was abandoned. The mold in its original configuration (as it was at the end of the previous contract)[1] was used again, except that the core was modified. The original core had an inclined four feed gating system. The tip of the core was tapered to provide a diaphragm gate which would feed the case from the projectile end of the neck (see Figure 8). This accomplished two things. The diaphragm gate eliminated the flow lines[2], and it provided more uniform distribution of glass in the material. It was believed that the latter would strengthen the neck enough to pass the drop test; however, it did not.

c. Case Configuration C

Because of this, the next step taken was to increase the neck thickness. This step, previously considered unacceptable, appeared to be the last alternative for solving the drop test failure problem and was therefore approved. The core was machined to decrease the inside diameter of the neck from 0.765 inch to 0.685 inch. This increased the wall thickness of the neck from 0.030 to 0.070 inch. In addition to the diameter change, the retaining bead tested in the neckless case was added. Two types of thick neck cases (see Figure 9) were tested. The straight configuration (round type 10) maintained the 0.070-inch wall thickness throughout the full length of the neck. This was done for strength and so that machining of the molded case required cutting off the top. The stepped configuration (round type 11) required an additional step (a 0.770-inch-diameter x 0.070-inch-deep counterbore), but provided a thin lip at the front of the cartridge which could obturate and seal the chamber. It also allowed material to be left on the aft end of the projectile to insure that the rotating band remained on the projectile. (On the unstepped projectile, nearly all the metal behind the rotating band had been removed.)

A number of rounds of each configuration were fired from the Mann barrel to determine pressures and velocities. The unstepped version had a peak pressure of 55,400 psi and velocity of 3,450 fps; the stepped had the same velocity but a peak pressure of 59,000 psi (37.0-gram charge for both). The unstepped case appeared preferable at this point.

It was decided that the integrity of the projectile after modification should be verified. Several rounds of each configuration were fired, and muzzle X-ray photographs were made (see Figures 10 and 11). Both types functioned satisfactorily.

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1 The mold was the same except that the cavity was modified during a previous change to increase the neck OD by 0.00[illegible] inch.

2 There was one flow line visible. This was due to a concentricity problem corrected later in the production mold.

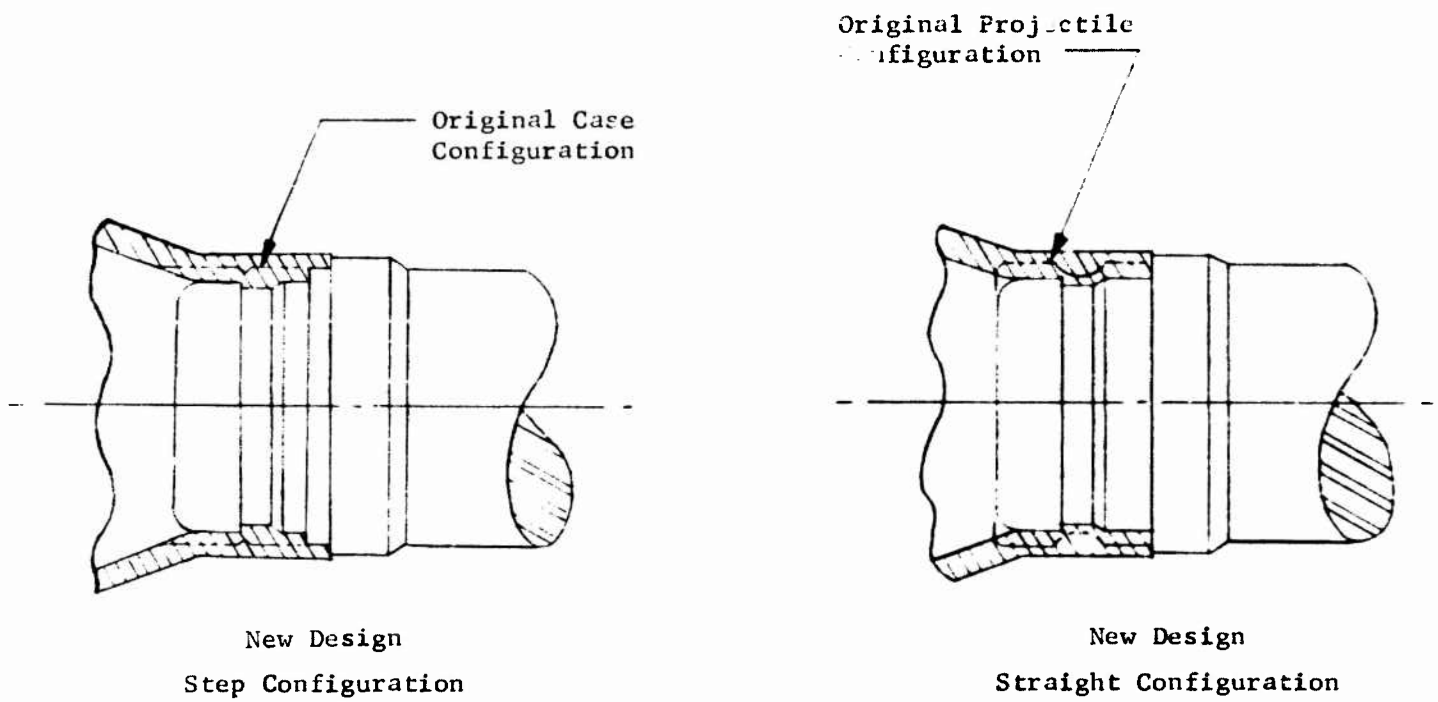

Figure 9. New (Thick Wall Neck) Case and Projectile Design

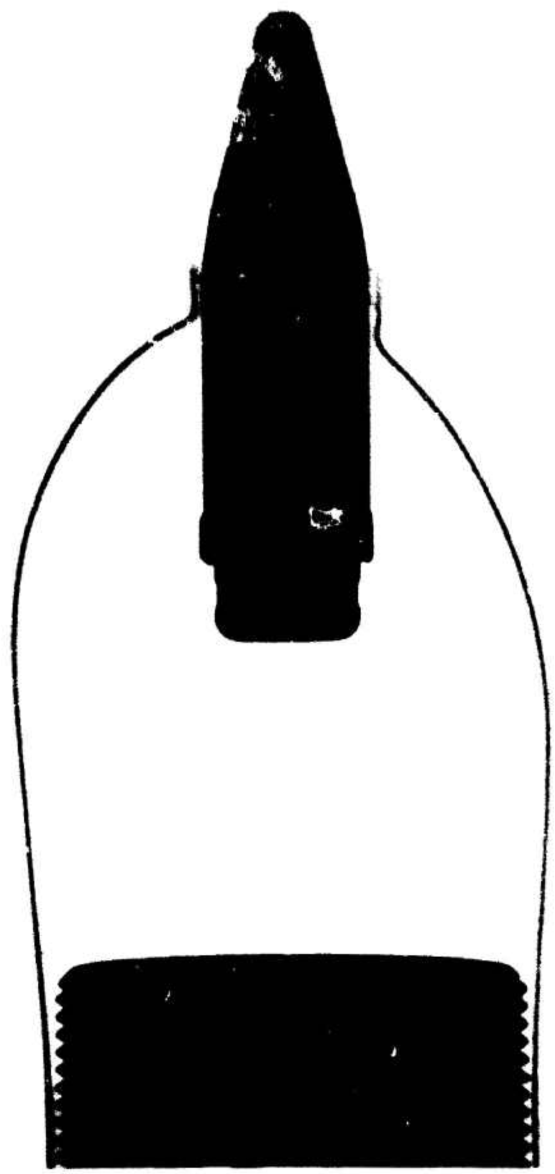

Figure 10. X-Ray Photograph, Straight Projectile

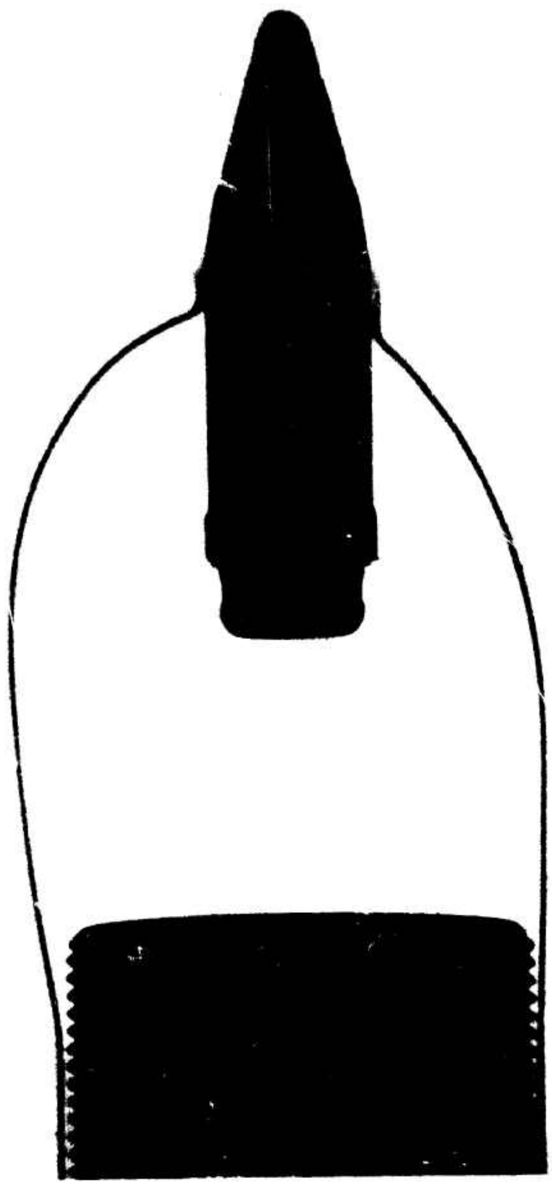

Figure 11. X-Ray Photograph, Stepped Projectile

Several rounds of both versions were fired from the M61 gun at ambient temperatures and functioned properly. Tests with six rounds of each, conditioned at -65^{0} were fired. All but one of the unstepped cases failed (four had neck separations, one had case/base separation). All of the stepped cases cycled without a failure. Based on these results, it was decided to proceed with the stepped configuration.

At this time, stability calculations for the stepped projectile were made and submitted to the Project Officer.

The CG locations and weights used were calculated and verified on the physical projectiles.

The basic equation used for calculating stability was:

$$S = \frac{\pi^2 A^2}{\rho n^2 d^5 B K_M} \; *$$

where: A = axial moment of inertia

ρ = air density = 2.376×10^{-3} slugs/ft^3

n = rifling twist rate = 25.4 calibers/turn

d = projectile diameter = 0.0654 ft

B = transverse moment of inertia - lb-sec^2 ft

K_M = pitching moment coefficient

For stability, S must be greater than unity.

K_M is an experimentally determined coefficient which relates center of pressure to the center of gravity in determining the overturning moment of the projectile. The center of pressure (CP) will be forward of the center of gravity (CG) in all cases. As projectile CG is moved forward toward the CP, the overturning moment is reduced and the projectile becomes more

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* Ballistic Research Laboratories Report No. 620 by H. P. Hitchcock.

stable. Most values for K_M are in the range of from 0.8 to 2.0. For these calculations, a K_M = 1.14 for the standard M55A2 projectile was used. (A 20mm ball T4 has a K_M = 1.14.) The CG of the modified projectile moved forward and hence reduced the K_M and increased stability.

The new K_M can be approximated by first finding the distance from CP to CG for both projectiles.

$$h = .0747 + .0443a + 1.0196b + .8032c + .2459d + \frac{.8083}{e}$$

where: h = distance from base to CP (calibers)

a = angle of boattail = 0°

b = length of boattail = 0 calibers

c = length of cylindrical part of body = 2.2 calibers

d = length of head = 1.5 calibers

e = radius of ogival arc = infinity

Substituting:

$$h = .0747 + .8032(2.2) + .2459(1.5) = 2.21 \text{ calibers} = 1.74 \text{ inch}$$

The distances from the base to the CG's are 1.05 inches for the M55A2 and 1.08 inches for the proposed projectile.

Therefore, the distances from CG's to CP's for both are:

Standard 1.74 - 1.05 = 0.69 inch

Modified 1.74 - 1.08 = 0.66 inch

K_M can be approximated by ratio:

$$\frac{K_M \text{ mod}}{K_M \text{ std}} = \frac{x_{mod}}{x_{std}} \qquad K_M \text{ std} = 1.14$$

$$K_{M \text{ mod}} = 1.14 \left(\frac{.66}{.69}\right) = 1.09$$

The stabilities can now be calculated by substituting in the basic equation:

$$S = \frac{\pi^2 A^2}{\rho n^2 d^5 B K_M}$$

Standard M55A2

$A = 3.875 \times 10^{-6}$ lb-sec^2-ft

$B = 2.34 \times 10^{-5}$ lb-sec^2-ft

$K_M = 1.14$

Substituting yields: $S = \underline{3.03}$

Modified M55A2

$A = 3.745 \times 10^{-6}$ lb-sec^2-ft

$B = 2.204 \times 10^{-5}$ lb-sec^2-ft

$K_M = 1.09$

Substituting yields: $S = \underline{3.14}$

By calculation, even though the axial of moment of inertia (A), an important stabilizing factor, was reduced by decreasing projectile diameter aft of the rifling band, this was compensated for by the forward shifting of the CG toward the CP. As a result, the modified projectile was more stable than the standard M55A2.

Per the Project Officer's request, additional Mann barrel tests were made with the stepped cases (round type 11) loaded with the maximum propellant charge (40.0 grams) which could be accomodated. All rounds were fired at ambient, and the peak pressure and velocity were determined to be 63,335 psi and 3,485 fps, respectively. Eighty percent of the cases failed at the neck.

At this point in the development, several new materials were available for evaluation. Several type 11 cases were molded using each of the plastics. The plastics tested were:

Huls 12 nylon/50 percent glass-impregnated - LNP version
Huls 12 nylon/50 percent glass-impregnated - Thermofil version
Dupont 6-12 nylon (high molecular weight)/43 percent glass-(short) impregnated - Formula #5066
Dupont 6-12 nylon (high molecular weight)/34 percent glass (with polymer modifier) - Formula #5067
Dupont 6-12 nylon (high molecular weight)/40 percent fybex "D" - Formula #5070
Dupont 6-12 nylon (high molecular weight)/20 percent fybex "D" +10 percent mineral filler - Formula #5071

The external dimensions of these cases were within the tolerances specified on the drawings. The rounds were tested at -65°F and +165°F by firing in the M61 gun. At -65°F, both of the Huls 12 materials performed satisfactorily, the DuPont formula 5066 had a 16-percent failure rate, and the remaining DuPont materials had a 70- to 100-percent failure rate. The types of failures experienced were neck separations, base/case separations, longitudinal cracks, and multiple breaks in various directions. At +165°F, all of the cases had neck separations (as this was considered a design problem it was not viewed as a failure of the material), the Huls 12 (LNP) and DuPont's #5066 and #5067 all functioned properly, the Huls 12 (thermofil) had 16 percent failures, and the other DuPont materials had a 33 percent failure rate. The failures experienced consisted of base/case joint separations or splits.

Based on these results, the Huls 12 nylon/50 percent glass-impregnated (LNP version) was established as the standard of design and was used in all subsequent molding.

It was decided at this point to develop the charge which would produce a velocity equal to that of the standard round (3380 fps). A series of tests indicated that a charge of 36.5 grams would produce the desired velocity with a corresponding pressure of 53,000 psi at ambient temperature.

The round had been experiencing various failures since the beginning of the contract. The two failures of the plastic case were separation of the neck from the case at the shoulder (see Figure 6) and cracking or failure of the base/case joint (see Figure 12). In an effort to determine the cause of the latter, the fit of the case in the base was examined. Both drawings and parts indicated that the aft end of the case was being flexed inward, creating a gap between the base and case chevrons. To alleviate this problem, the new mold segments (the portions of the mold which form the chevrons on the case) were designed to provide a lighter (line-to-line to 0.005-inch press) fit. In addition to this, later modifications to the base were required to eliminate the base/case joint failure. Several solutions to the neck failure problem were tested: (1) the projectile retaining bead was machined out of several cases as it appeared possible that the necks were being pulled off by the

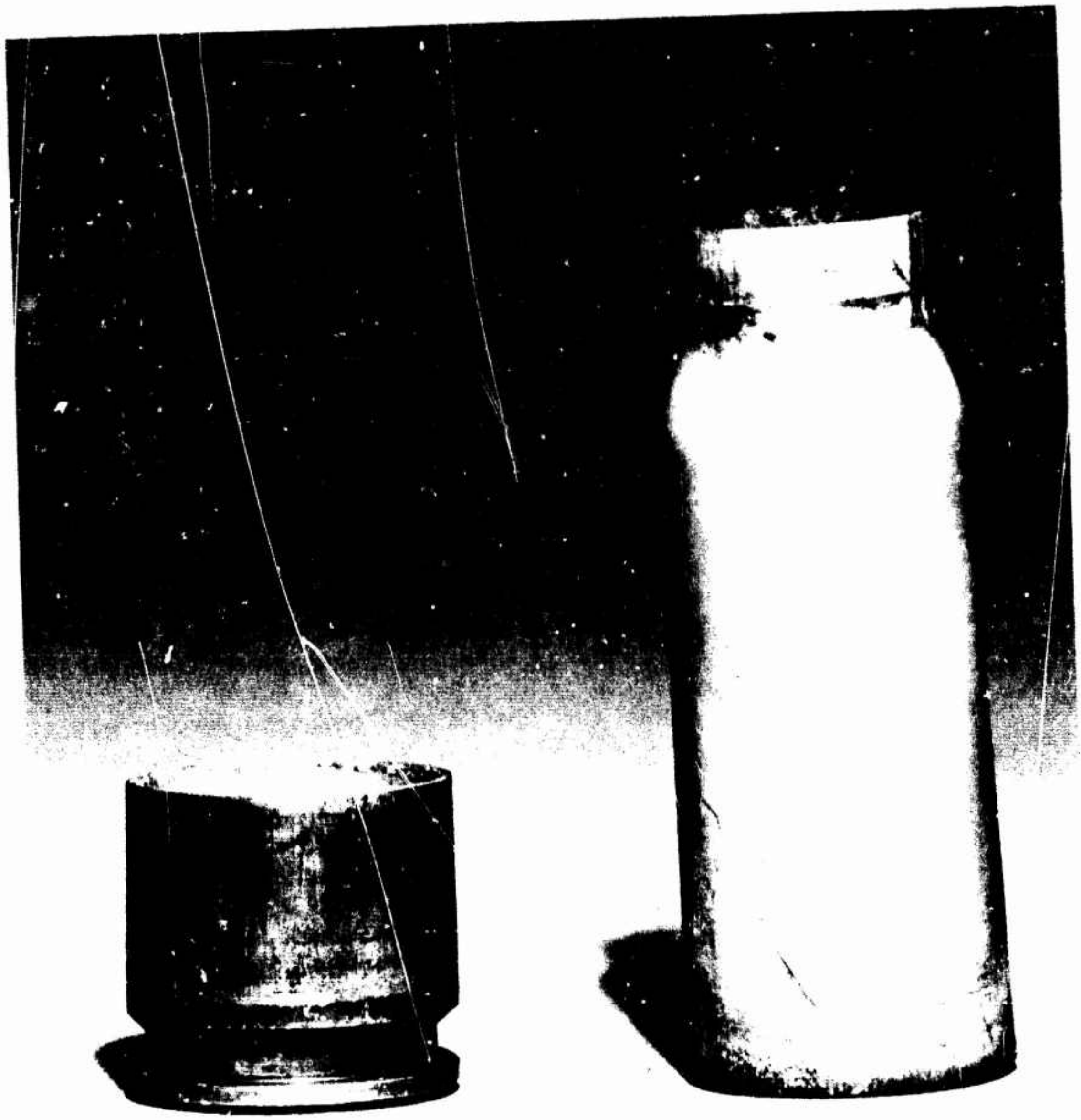


Figure 12. Typical Base/Case Joint Failure

projectile; (2) a stress analysis calculation of the area of the failure indicated an insufficient thickness and the shoulder thickness was increased accordingly (two thicknesses were tested, see Figure 13); (3) the neck thickness was reduced, from 0.070 to 0.045, as it was felt that the thicker wall was not able to obturate sufficiently fast to accept the rapid pressure increase without failing. None of these solved the neck separation problem.

d. Case Configuration D

The new mold was completed and the cases molded from it (type 21) were expected to be superior in that the chevron area had been modified, as previously explained, and the new mold was designed to allow optimum molding pressure (15,000 psi injection and 10,000 psi hold). Pressures from the beginning of the contract had been low (5,000 to 7,500 psi injection and 2,500 to 5,000 psi hold). The low molding pressures are believed to have adversely affected the properties of the plastic and possibly have been a contributing factor in the neck separation problem.

Rounds using cases molded in the new mold were loaded and test fired, in the M61 gun, at -65°F and +165°F. All of the cases fired cold functioned properly. The hot rounds were less satisfactory. All of them had neck separations, and seventeen percent had base/case joint failures. The joint failures were later to be solved, but the neck separations remained.

To solve the base/case joint failure, several modifications were tried: (1) the bases and cases were lubricated with Electrofilm Lubribond-A to alleviate frictional drag between the round and the chamber; (2) the base was shortened by 0.008 inch to 0.010 inch and electrofilmed (work done on a previous contract had shown that cases which were too long broke at the base/case joint in compression during chambering); and later shims were added to the front of the case to lengthen it by 0.020 inch and 0.030 inch. (The cases modified as noted in (2), above, had a higher failure rate than the standard length case. The break now appeared to be a tensile rather than a compressive failure.)

The last efforts made to eliminate the neck separation problems consisted of (1) tapering the neck internally starting at the step in the neck to the front end of the case (see Figure 14) to provide better obturation and prevent gases from leaking back around the neck; (2) the inside of the neck was machined to provide a 0.045-inch wall thickness (this was done previously but to cases molded at low pressure) as an attempt to improve obturation and to reduce pressure frontal surface area; and (3) the inside of the neck was fluted (see Figure 15) as a compromise between the old thin wall neck design and the more rigid thick wall.

Lengthening the case by 0.030 solved the base/case joint failure problem. The mold length was increased by that amount and cases subsequently molded and fired functioned without repeating this failure. The neck separation problem remained unsolved.

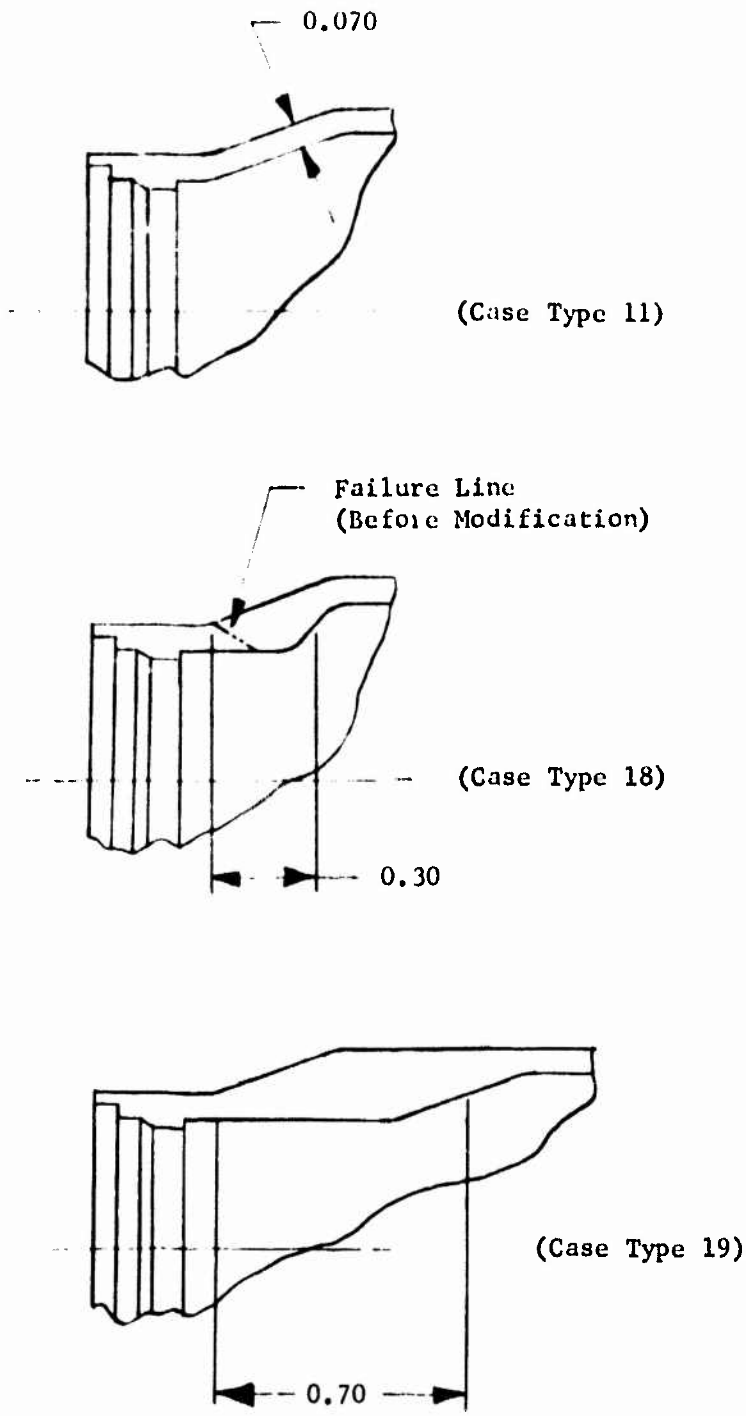


Figure 13. Shoulder Modifications
(Scale: 2/1)

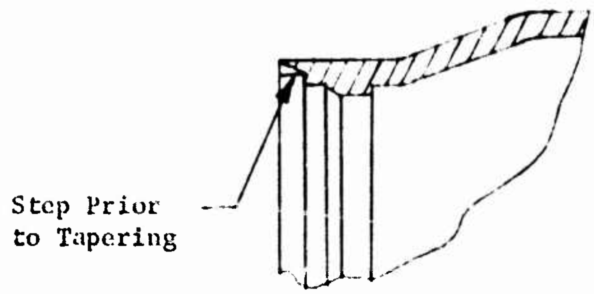


Figure 14. Tapered Internal Step

(Case Type 22)

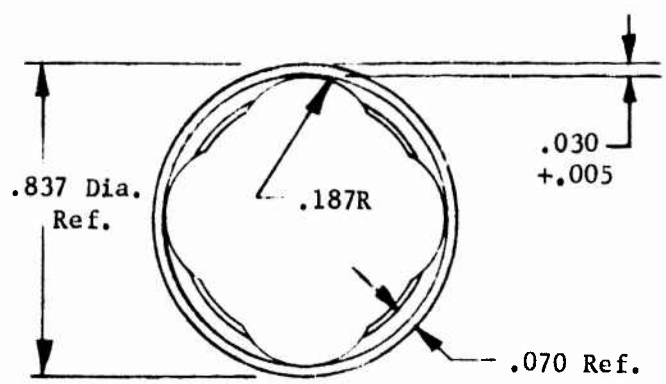


Figure 15. Fluted Neck (Case Type 32)
View of Neck from Front of Case Looking Aft)

e. Case Configuration E

After a consultation with the Project Officer concerning the neck separation, it was decided to return to the thin wall neck configuration, and this (case type 36) was the case which was delivered. Although this final case design was identical to the configuration of the case at the close of the last contract, it had a distinct advantage in that it was molded using a diaphragm gate which eliminated the flow lines. The type 36 cases were tested at -65°F, +165°F, and ambient temperatures and functioned without a failure of any type. These rounds were loaded with 37.0 grams, and pressure and velocity readings were taken. At ambient temperature, the velocity was 3350 fps with a corresponding peak pressure of 47,500 psi. Typical pressure versus time curves are shown in Figure 16.

The various case types tested, along with the test results, are described in Table II.

2. BASE DEVELOPMENT

The physical dimensions of the base were the same as those of the base furnished on the previous contract with exceptions as noted in this subsection.

The bases used with case type 1 through type 14 were identical to those used on the last contract. These bases suffered circumferential splits or separations 0.35 inch back from the open end. (See Figure 17.) This places the crack at the thinnest point of the first chevron. In the early part of the program, it was believed that this failure was a result of a lack of fillets in the corners of the chevrons and the exceptionally heavy press fit between the case and the base (0.015 to 0.020 inch). The fillets could not be corrected in the cases already made, but they were added to the production bases. To relieve the heavy press fit on existing bases, a 0.003-inch cut was taken on the chevrons (at an angle (4°35') matching the chevron joint, increasing the ID by 0.006). Bases bearing this modification were used with case types 15 through 20. This modification reduced the incidence of base failures (from 16 percent to 5.5 percent) but did not eliminate them.

The remainder of the bases used on the contract were from the production run. These bases were the same as those used on the previous contract. Of 23 rounds (utilizing the production base and type 21 or 22 case) fired at +165°F and 12 rounds fired at -65°F fired from the M61 gun, nine of the bases were cracked circumferentially 0.35 inch from base/case joint (at first chevron), three separated at the same location, and three were eroded. This was a base failure rate of 60 percent, the highest ever experienced on this contract.

The base failures had been experienced for some time, but they had been attributed to the heavy press fit (0.015 to 0.020 inch) of the case into

TABLE II. DEVELOPMENTAL TESTING RESULTS

CASE TYPE NO.	BASE TYPE NO.	DESCRIPTION	WEAPON USED	TEST TEMP.	NO. OF ROUNDS FIRED						REMARKS
					TOTAL	SUCCESSFUL	FAILED*				
							N	BC	B	L	
1	1	Case and base same as previous contract	M61	Ambient	30	25			5		Huls 12 nylon/50% glass (Thermofil)
2 (New design)	1	Case with internal molded collar-diaphragm gate 1st new design	Mann	Ambient	6	2	3			1	Huls 12/50% glass/Thermofil
			M61	Ambient	6		6		1		Huls 12/50% glass/Thermofil
			M61	Ambient	6	3	3		1		Dupont No. 5067
			M61	Ambient	5	1		1	3		Dupont No. 5066
			M61	Ambient	6		4	1	3		Dupont 6-12 nylon/43% glass
3	1	Case same as type 2 except neck O.D. increased by 0.004	M61	Ambient	6		5		3		Huls 12/50% glass/Thermofil
					6	1	1	1	3		Dupont No. 5066
					6	1	2	4	1		Dupont No. 5067
4	1	Case same as type 3 except neck machined off & collar machined cut to neck I.D. - 0.030	Mann	Ambient	2						Huls 12/50% glass/Thermofil Both cases failed at first chevron
5	1	Same as type 4 except neck removed to retaining bead	Mann	Ambient	2		2				Huls 12/50% glass/Thermofil
6	1	Same as type 1 except neck removed to retaining bead	Mann	Ambient	1		1				Huls 12/50% glass/Thermofil
7	1	Same as type 5 except collar machined into 0.120 wide bead	Mann	Ambient	3	2	1				Huls 12/50% glass/Thermofil
			M61	Ambient	6	6					Huls 12/50% glass/Thermofil
8	1	Gate increased from 0.030 to 0.060	M61	Ambient	6		6				Huls 12/50% glass/Thermofil

*Failures designated by type: (N) Neck Separation, (BC) Base/Case Joint Failure, (B) Base Failure (crack or separation), (L) Longitudinal Crack in Case

TABLE II. DEVELOPMENTAL TESTING RESULTS (Continued)

CASE TYPE NO.	BASE TYPE NO.	DESCRIPTION	WEAPON USED	TEST TEMP.	NO. OF ROUNDS FIRED TOTAL	SUCCESSFUL	FAILED* N	BC	B	L	REMARKS
9	1	Same as type 1 except neck O.D. 0.004 larger gate changed to diaphragm	M61	Ambient	12	12					Huls 12/50% glass/Thermofil
			M61	Ambient	6	6					Huls 12/50% glass/LNP
			M61	-65°F	6	5				1	Huls 12/50% glass/Thermofil
			M61	-65°F	6	6					Huls 12/50% glass/LNP
10	1	Neck wall thickness increased from 0.030 to 0.070 wide bead molded in	Mann	Ambient	4	4					Huls 12/50% glass/LNP
			M61	Ambient	3	2			1		Huls 12/50% glass/LNP
			M61	-65°F	6	1	4	1			Huls 12/50% glass/LNP
11	1	Same as type 10 except neck is stepped	Mann	Ambient	5	5					Huls 12/50% glass/LNP
			Mann	Ambient	6	1	5				Huls 12/50% glass/LNP (40 Gm Chg)
			Mann	Ambient	6	6					Dupont No. 5066 (Chg Devel)
			M61	Ambient	7	4	2		1		Huls 12/50% glass/LNP
			M61	Ambient	6		6				Huls 11/30% glass/LNP
			M61	-65°F	24	17	3	3		1	Huls 12/50% glass/LNP
			M61	-65°F	6	6					Huls 12/50% glass/Thermofil
			M61	-65°F	6	5				1	Dupont 5066
			M61	-65°F	6	2				4	Dupont 5067
			M61	-65°F	5		1	5		3	Dupont 5070
			M61	-65°F	6	1	1	5		3	Dupont 5071
			M61	+165°F	12		12		7		Huls 12/50% glass/LNP
			M61	+165°F	6		6	1	2		Huls 12/50% glass/Thermofil
			M61	+165°F	6		6		6		Dupont 5066
			M61	+165°F	6		6		6		Dupont 5067
			M61	+165°F	7		7	2			Dupont 5070
			M61	+165°F	6		6	2			Dupont 5071
12	1	Same as type 11 except bead length reduced to 0.060	M61	+165°F	3		3	1	2		Huls 12/50% glass/Thermofil

*Failures designated by type: (N) Neck Separation, (BC) Base/Case Joint Failure, (B) Base Failure (crack or separation), (L) Longitudinal Crack in Case

TABLE II. DEVELOPMENTAL TESTING RESULTS (Continued)

CASE TYPE NO.	BASE TYPE NO.	DESCRIPTION	WEAPON USED	TEST TEMP.	NO. OF ROUNDS FIRED						REMARKS
					TOTAL	SUCCESSFUL	FAILED*				
							N	BC	B	L	
13	1	Same as type 1 except O.D. of neck turned down to 0.835	M61	-65°F	6	6					Huls 12/50% glass/LNP
14	1	Same as type 11 except O.D. reduced by 0.005 (molded)	M61 M61 M61	Ambient -65°F +165°F	6 6 3	 6 	 3	6 1	 1		Huls 12/50% glass/LNP Huls 12/50% glass/LNP Huls 12/50% glass/LNP
15	2	Base I.D. increased by 0.006	M61 M61 M61	Ambient -65°F +165°F	11 11 5	7 10 	 5	4 1 	 2		Huls 12/50% glass/LNP Huls 12/50% glass/LNP Huls 12/50% glass/LNP
16	2	Same as type 14 except projectile retaining bead machined out	M61	+165°F	1		1				Huls 12/50% glass/LNP
17	2	Same as type 16 except O.D. of neck reduced 0.004	M61	+165°F	1		1				Huls 12/50% glass/LNP
18	2	Same as type 15 except shoulder wall is 0.30 thick	M61 M61	-65°F +165°F	6 6	4 	 6		2 6		Huls 12/50% glass/LNP Huls 12/50% glass/LNP (Bases eroded)
19	2	Same as type 15 except shoulder wall is 0.70 thick	M61 M61 M61	Ambient -65°F +165°F	[illegible] 5 5	1 1 	 2 2	 1 	1 4	1 4 	Huls 12/50% glass/LNP Huls 12/50% glass/LNP Huls 12/50% glass/LNP
20	2	Same as type 15 except neck wall is 0.045 thick (Machined)	M61 M61	-65°F +165°F	5 6	2 	2 6		 5	2 	Huls 12/50% glass/LNP Huls 12/50% glass/LNP
21 (New mold)	3 (Production bases)	Cases from production (new) mold and bases from production run	M61 M61	-65°F +165°F	6 11	5 	 11	 2	1 5		Huls 12/50% glass/LNP Huls 12/50% glass/LNP

*Failures designated by type: (N) Neck Separation, (BC) Base/Case Joint Failure, (B) Base Failure (crack or separation), (L) Longitudinal Crack in Case

TABLE II. DEVELOPMENTAL TESTING RESULTS (Continued)

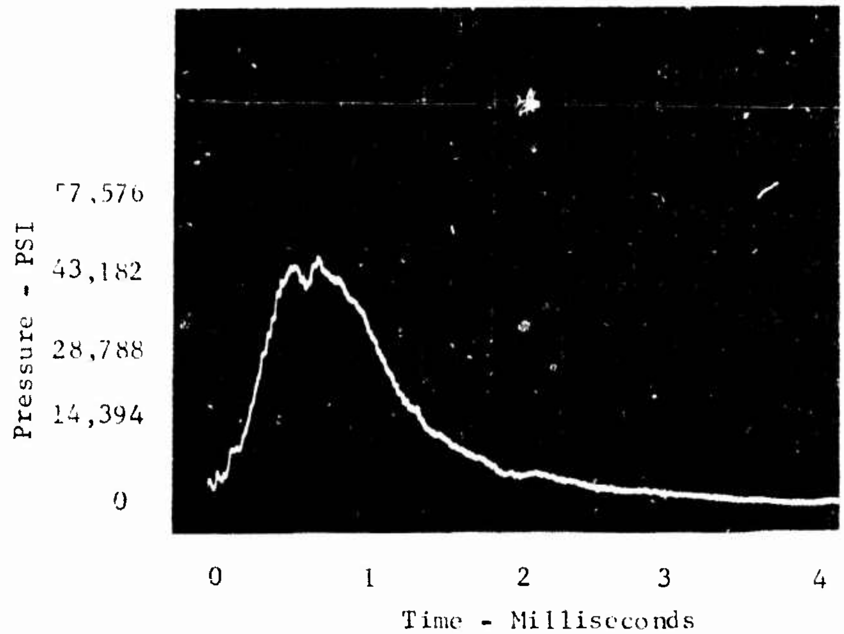
CASE TYPE NO.	BASE TYPE NO.	DESCRIPTION	WEAPON USED	TEST TEMP.	NO. OF ROUNDS FIRED TOTAL	SUCCESSFUL	FAILED* N	BC	B	L	REMARKS
22	3	Same as type 21 except I.D. of step is tapered	M61	-65°F	6	4		1		1	Huls 12/50% glass/LNP
			M61	+165°F	6		6	6			Huls 12/50% glass/LNP
23	3	Base lubricated	M61	+165°F	6		6	1	1		Huls 12/50% glass/LNP
			M61	+165°F	5		5	4			Huls 12/50% glass/Thermofil
			M61	+165°F	3		3	3			Huls 1[illegible]50% glass/Thermofil
			M61	+165°F	5		5	5			Dupont 6-12 Nylon/43% glass
24	4	Base same as type 3 except 0°45' taper cut taken on rear of base	M61	+165°F	6		6		3		Huls 12/50% glass/LNP
25	3	Same as type 21 except neck I.D. 0.045 thick (Machined)	M61	+165°F	6		6	4	1		Huls 12/50% glass/LNP
26	3	Bases stress relieved	M61	+165°F	6		6	5			Huls 12/50% glass/LNP
27	3	Case and base lubricated	M61	+165°F	6		6	1			Huls 12/50% glass/LNP
28	3	Same as type 21 except chevrons on case cut back 0.015 Bases lubricated	M61	+165°F	6		6	3			Huls 12/50% glass/LNP
29	5	Cut 0.008 to 0.010 taken across rear of base and base lubricated	M61	+165°F	5		5	5			Huls 12/50% glass/LNP

*Failures designated by type: (N) Neck Separation, (BC) Base/Case Joint Failure, (B) Base Failure (crack or separation), (L) Longitudinal Crack in Case

TABLE II. DEVELOPMENTAL TESTING RESULTS (Concluded)

CASE TYPE NO.	BASE TYPE NO.	DESCRIPTION	WEAPON USED	TEST TEMP.	NO. OF ROUNDS FIRED						REMARKS
					TOTAL	SUCCESSFUL	FAILED*				
							N	BC	B	L	
30	3	0.020 shim on front of case. Base lubricated.	M61	+165°F	6		6				Huls 12/50% glass/LNP
31	3	0.030 shim on front of case. Base lubricated.	M61	+165°F	6		6				Huls 12/50% glass/LNP
32	3	Same as type 21 except neck fluted and base lubricated	M61	+165°F	6		6	4			Huls 12/50% glass/LNP
33	3	Same as type 21 except case 0.010 longer (molded) and base lubricated	M61	+165°F	6		6	6			Huls 12/50% glass/LNP
34	3	Same as type 21 except case 0.030 longer (molded) and base stress relieved	M61	+165°F	6		6	2	3		Huls 12/50% glass/LNP
35	3	Core modified to provide thin wall (type 1) neck and "V" retaining bead	M61 M61	+165°F -65°F	6 6	5 2		1		 4	Huls 12/50% glass/LNP Huls 12/50% glass/LNP
36	3	Gate opening increased	M61 M61 Mann	-65°F +165°F Ambient	6 6 6	6 6 6					Huls 12/50% glass/LNP Huls 12/50% glass/LNP Huls 12/50% glass/LNP
TOTAL					497	195 (39.2%)					

*Failures designated by type: (N) Neck Separation, (BC) Base/Case Joint Failure, (B) Base Failure (crack or separation), (L) Longitudinal Crack in Case



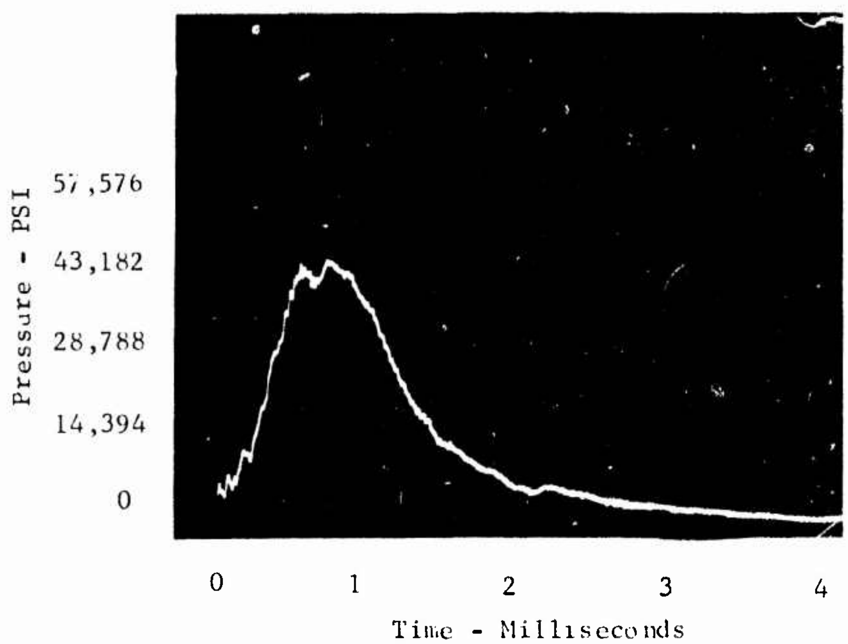


Figure 16. Oscilloscope Traces of Pressure Versus Time Curve for Type Plastic 36 Plastic/Aluminum Cartridge Case

Figure 17. Typical Base Failures

the base and sharp fillets and corners on the base. Since the new cases had been corrected dimensionally to make the fit light and the production bases had added or larger fillets and corners, the cause for the failures must have been from another source, since the failures still occurred at an even higher rate on the altered bases.

After carefully examining the bases that failed and comparing them to bases from the previous contract which had not failed, it was determined that the new bases were not able to distort enough to seat firmly on the sloped bolt face. This caused them to cock in the chamber and fail circumferentially. Examination showed the hardness of the new bases to be the same as that of the old bases, and the material had been certified to be the same type (7075-T6). Another possible variation in material which might cause the brittleness was the forming process for the bar stock (rolled versus extruded). It was felt that this type of deviation was one which must be tolerated in a production item, so a means was sought to compensate for such differences. Three processes were employed to solve the base crack problem: (1) lubricating the base with electro-film Lubribond A (to eliminate frictional drag between the base and the chamber); (2) machining a $0^{o}45'$ taper on the rear surface of the base (to provide partial contact of the base and bolt prior to distortion); and (3) stress relieving the bases after machining. The electrofilm and the taper worked; the stress relief did not. It was decided to solve the problem by using the electrofilm.

The erosion of the bases was a relatively new problem, having occurred only when the production bases were used. It is believed that this problem resulted from either or both of the following: (1) the brittleness of the material which caused the circumferential cracks also caused localized failures, resulting in microscopic cracks through which the burning gases escaped; and (2) in comparing the bases from the previous contract to the new bases, the radius of the inside corner of the main cavity is 0.25 inch on the new bases versus 0.30 inch on the old. The drawing specifies a radius of 0.30 — 0.05 inch which indicates the new cases to be within the specified tolerance, but the loss of material due to the smaller radius is believed to be a contributing factor to failures and erosion in that area.

A rubber seal, made of Dow Corning silicone rubber, was designed. This seal fits in the aft end of the case (see Figure 18) and seats in the base. The rubber seal prevents the escape of the high temperature, high pressure propellant gases through cracks on the base/case chevron joint, and this eliminates erosion.

The bases which were delivered were electrofilm-coated and furnished with the new rubber seal. The internal volume of the case was decreased by 0.06 cubic inches to 2.38 cubic inches by the addition of the rubber seal.

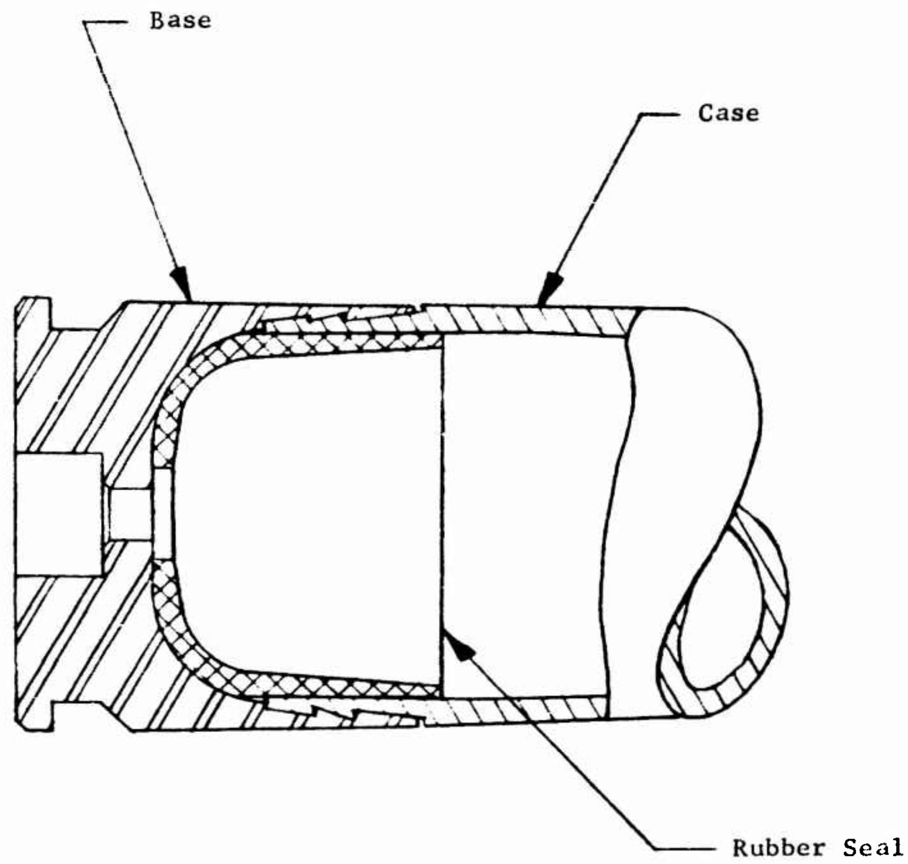


Figure 18. Rubber Seal (Installed)

3. MOLDING CYCLE CONSIDERATIONS

Throughout the development program, all molding of the plastic body was performed on a 75 ton, 3 ounce injection molding screw ram machine, model number 75 manufactured by the New Britain Machine Company, New Britain, Conn. The molding parameters which were varied and their effects on the case performance are discussed below.

a. Temperatures

The melt temperatures utilized throughout were those recommended by the various resin manufacturers. The melt temperatures for the various 6-12 nylon resins were in the 520 to 530^{O}F range and for the type 12 resins in the 480 to 490^{O}F range.

b. Pressures

The injection molding cycle utilizes two pressure stages which are preset by the operator. The first stage is the pressure during injection of the molten plastic into the mold. As soon as the mold is filled the machine switches to the second stage pressure which is maintained until the gate solidifies. The second stage or dwell pressure prevents warpage and provides dimensional stability of the molded part. The recommended pressures for molding glass filled nylons are 15,000 to 20,000 psi for the first stage and 8,000 to 12,000 psi for the second stage.

The molding cycle developed on the previous contract utilized 20,000 psi for both the first and second stages. This was necessary to maintain the dimensions and tolerances required for successful operation of the case under all environmental conditions. These pressures were also used when molding case configurations A and B.

When the mold was changed to configuration C, which utilized a full diaphragm gate to eliminate the flow lines, the cases were in the order of 0.010 to 0.015 inch larger on the external surfaces when molded at the original pressures. In order to mold cases which would fit in the chamber the pressures were reduced to a pressure range of 5000 to 7000 psi for the first stage and 2500 to 5000 psi for the second stage. While this procedure provided cases which would fit the chamber and allow testing to continue it was believed that the low molding pressures adversely affected the properties of the plastic and could have been a contributing factor in the neck separation problem.

The new mold for case configurations D and E was designed to provide cases with the required dimensions under the recommended injection pressures. However subsequent tests of these cases indicated that the neck separations were a design problem and were not due to the properties of the molded plastic material. Reducing the neck thickness from 0.070 to 0.030 inch (configuration D to E) solved the neck separation problem. The previous molding

pressure of 20,000 psi for both the first and second stages was also used for the configuration E cases to maintain the dimensions and tolerances required.

The final mold and molding record for the configuration E cases is shown in Figure 19.

4. ALTERNATIVE BASE/CASE JOINT

The chevron portion of the plastic aluminum cartridge is the prime area in which improvements to facilitate manufacture and reduce cost could be made. Machining of the close tolerance chevrons in the base represent a large part of its manufacturing cost. The parts of the mold which form the chevrons on the plastic case (the split mold segments) are also the parts which cause most of the mold's complexity.

Toward the close of the contract, the Project Officer suggested that an alternate method of joining the plastic case to the aluminum base be investigated. A successful metal-to-plastic bonding process had been developed for a plastic rotating band on the 20mm projectile during an Air Force development project by DeBell and Richardson Inc., Enfield, Connecticut. The plastic body and aluminum base were also bonded by this organization.

To test this bond in this application, the chevrons were machined off of several type 21 cases and omitted on 50 production bases. The parts were slip taper fit, and the bond was along the common surface. (See Figures 20 and 21.) Several of the cases were restrained (base mechanically held against the base) while the rest were unrestrained during the curing operation. These cases were designated type "R" and "U", respectively. In rough-handling tests, both cases performed satisfactorily. Two of each type were fired on the M61 gun at ambient temperature. One type "U" case failed at the joint. The type "R" cases performed well by firing and extracting without separation. Six of the type "R" cases were then fired after conditioning at +165°F. While three of the cases did not fire due to a gun malfunction, none of the six held together at the bond joint. It was concluded that the bond strength or joint design was not sufficient at the high temperature to withstand the gun handling or firing loads. The type "R" cases performed well enough at ambient conditions to warrant additional investigation; however, tests performed during this contract are not conclusive.

M O L D A N D M O L D I N G R E C O R D	PLASTIC DEPT. 168

DATE: Feb. 4, 1974

CONTRACT NO: CW3427.01

TITLE 20mm Case	PART NO. 53593-40002	DWG. NO. 54593-40002, Rev. K
MOLD TYPE Conventional	MOLD TOOL NO. SKM-140	MOLD VENDOR AAI
MOLD SIZE 12 X 8 X 10	MOLD WT. 250 Pounds	NO. OF CAVITIES One
TYPE OF KNOCKOUT Mech	NOZZLE TYPE Pressure	NOZZLE RADIUS 1/2"
NOZZLE ORIFICE 0.125	GROSS WT. SHOT 29.2 Gms.	NET WT. SHOT -
SPRUE AND RUNNER WT. 22 GMS	WT/100 PARTS 46.2 Lbs.	PART SIZE CU. IN. 0.880

MATERIAL SPECIFICATIONS: HULS/LNP 12 Nylon, 50% F.G.

Product No. LNP-SF-100-10 NAT

MATERIAL VENDOR: LNP BUYER:

PRESS NO. 2-NB	PRESS SIZE 75 ton - 3 oz.	PRESS TYPE Injection

TEMPERATURES °F				PRESSURES PSI	
REAR	490			INJECT 1st STAGE HIGH	20,000
CENTER	-			INJECT 2nd STAGE LOW	20,000
				CLAMP (TONS)	60
FRONT	490			BACK (LBS)	None
NOZZLE	480	MELT	490	OTHER	-
THROAT	Hot			MISC. ITEMS	-
MOLD STATIONARY	150			RELEASE	None
MOLD MOVABLE	150			SECONDARY OPERATION	-

CYCLE TIME SECS.			
CLAMP CLOSED	45	SCREW SPEED 76 RPM	SCREW SIZE 1.42"
INJECT FORWARD	15	RAM CALIBRATE 7/8"	PAD 1/8"
INJECT 1st STAGE HIGH	2	RAM FORWARD SPEED Fast	
INJECT 2nd STAGE LOW	13	TYPE OF CYCLE Semi-Auto.	
CLAMP OPEN	-	QUANTITY PARTS TO BE MOLDED 2500	
SCREW DELAY	None	ENGINEERING R. Schnepfe	PLANNING J. Graham
TOTAL CYCLE	70 Semi-Auto Hand Inserted Split Collar	SET UP J. Marion	OPERATOR J. Marion
		SEE OVER FOR NOTES	

Figure 19. Mold and Molding Record

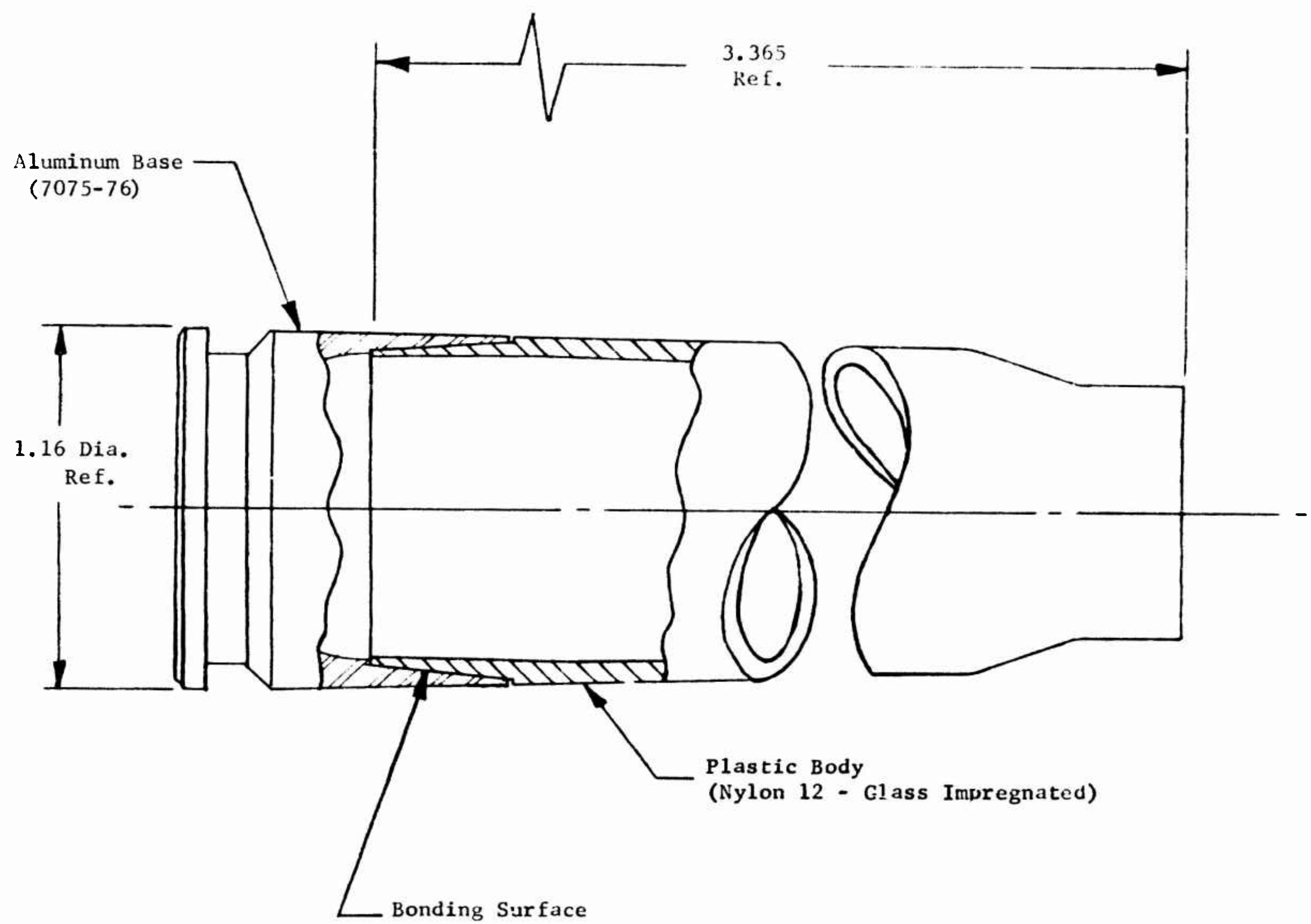


Figure 20. 20mm Plastic/Aluminum Cartridge Case Alternative Base/Case Joint

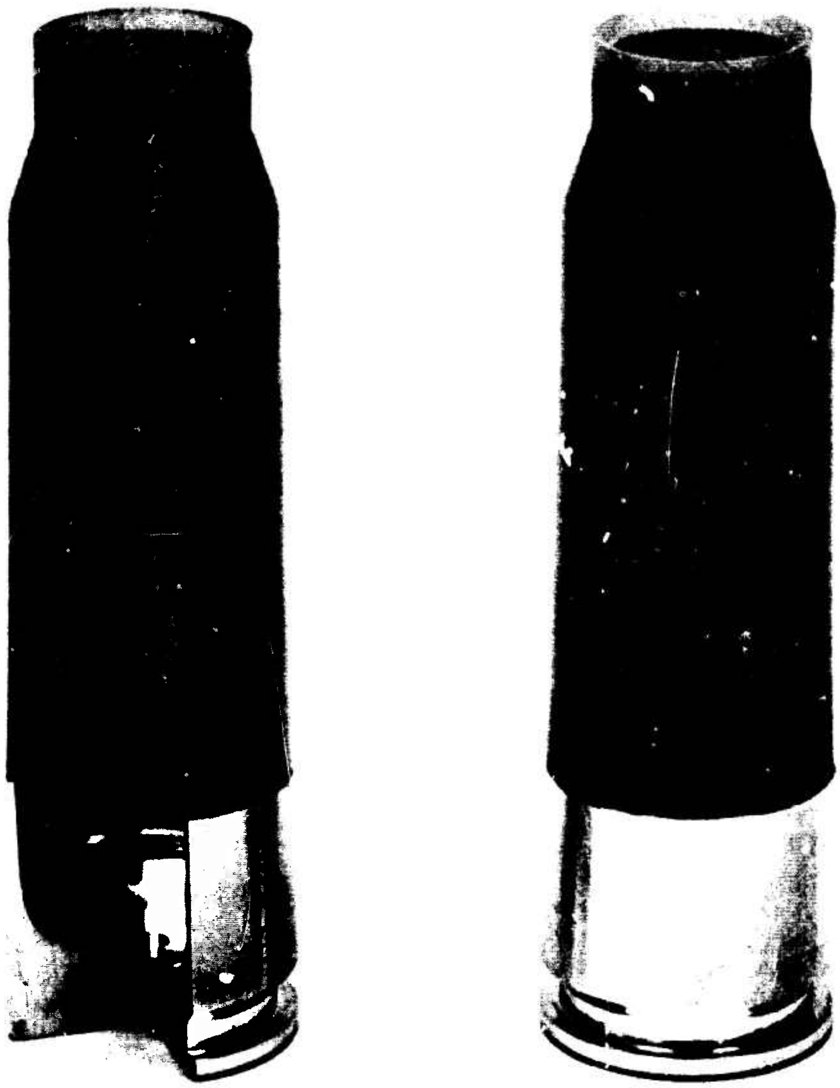


Figure 21. Cutaway of Alternate Base/Case Joint

SECTION V

CONCLUSIONS AND RECOMMENDATIONS

Based upon the numerous case modifications and subsequent test results, it is evident that temperature extreme testing remains a problem area affecting case integrity. Case failure at low temperatures tended to be limited to a longitudinal crack which did not impair performance or gun operation. High temperature failures tended to be more serious due to the higher pressures and temperatures encountered as well as the lowered mechanical properties of the case materials at high temperatures.

Initial efforts to improve the case resistance to rough handling consisted generally of increasing the thicknesses of the case wall in some areas. The thickness of the neck was doubled. The heavier sections, while greatly improving rough-handling resistance, tended to degrade the case integrity at firing. It became apparent that in some areas, particularly the case neck and the tapered area just behind the neck, the heavier the case wall, the more severe the failure at firing. Most of these failures were neck separations. Therefore, a situation exists where some rough-handling resistance must be sacrificed in order to gain case strength at firing. More development will be necessary to better define this trade-off and to arrive at some optimum wall thickness that will provide an acceptable set of properties to withstand both conditions.

The occasional base failures were of two types: (1) circumferential splits occurring at the fillet of one of the buttresses, and (2) longitudinal splits with a base burn-through. The circumferential splits occurred approximately 70 percent of the time when fired hot (+165^{o}F) and 30 percent of the time at ambient, and the burn-throughs occurred predominantly with the hot firings since these experience much higher gas pressures and temperatures than normal and mechanical properties of the aluminum are reduced.

The exact reasons or causes of the base failures could not be isolated during development, but some factors known to reduce base failure incidence have been identified. It is of critical importance that the base fit closely with the chamber with little or no clearance on the diameter to prevent cocking which contributes to longitudinal splits and burn-throughs. In machining the buttresses, it is important that the fillet radii be maintained to avoid creating too severe a stress concentration point which could cause a circumferential split at the buttress. The seal at the body/base joint must be maintained to avoid high pressure leaks which would, in the presence of air, cause the aluminum to burn. Once the aluminum begins to burn, the pressures and temperatures become so excessive that a base burn-through occurs. The deformations evident on failed bases indicate the presence of tremendously high pressures. Therefore, the rubber seal has been added internally to prevent leaks at the joint and subsequent burn-throughs. To avoid high stresses due to friction with the chamber at firing, the outside diameter of the base is coated with dry lubricant. This serves to eliminate circumferential splits at the buttresses.

An additional theory concerning the increased number of base failures during this program over those which occurred on the previous development which established basic feasibility is one which involves the method of production of the 7075-T6 aluminum bar stock. On the previous program, the bases were fabricated from drawn bar while those on this program were fabricated from extruded bar. All listed mechanical properties are the same except for tensile strength. The extruded bar used on this program has a tensile strength approximately 10 percent higher than the drawn bar used previously, but this higher tensile did not improve integrity. Hardness checks proved both types to be identical but higher than the listed hardness for 7075-T6 which might have caused brittleness. Since the manufacturing processes were different, there is a possibility that some subtle difference existed in the mechanical properties of the extruded bar that led to increased numbers of failures. Because at firing the bases are highly stressed, any inherent weakness would become evident in the form of failures.

It is recommended that the problem concerning the aluminum stock for the bases, as discussed above, be investigated to determine the reason for the failures and to establish a specification for the proper material. A continuing investigation of new plastic resins to meet the rough handling and bring requirements under the extreme temperature conditions is also warrented.

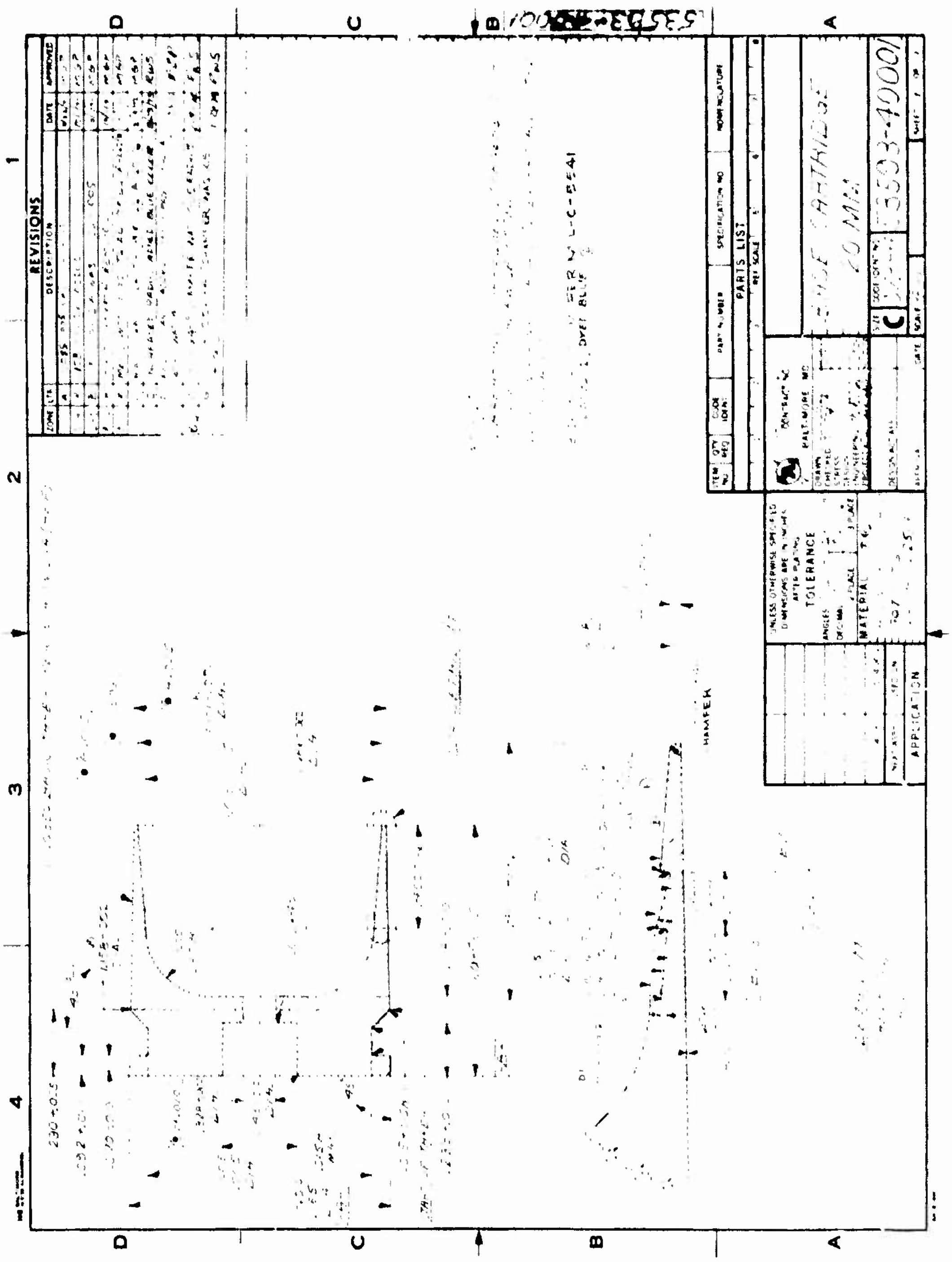
As a final recommendation, it is felt that the case assembly utilizing a bonded joint between the plastic body and aluminum base merits further investigation and possibly additional development. The limited testing performed during this program with the bonded joint was relatively successful and the design showed promise. The advantages to using a bonded joint are the elimination of the locking buttresses which, in the aluminum part, require a close tolerance machining operation and the simplification of the mold which produces the plastic body.

APPENDIX I

20MM CARTRIDGE CASE DRAWINGS

This appendix consists of the following 20mm cartridge case drawings:

53593-40001	Cartridge Base
53593-40002	Plastic Case
53593-40014	Rubber Seal
53593-40003	Case Assembly
53593-40012	Cartridge Assembly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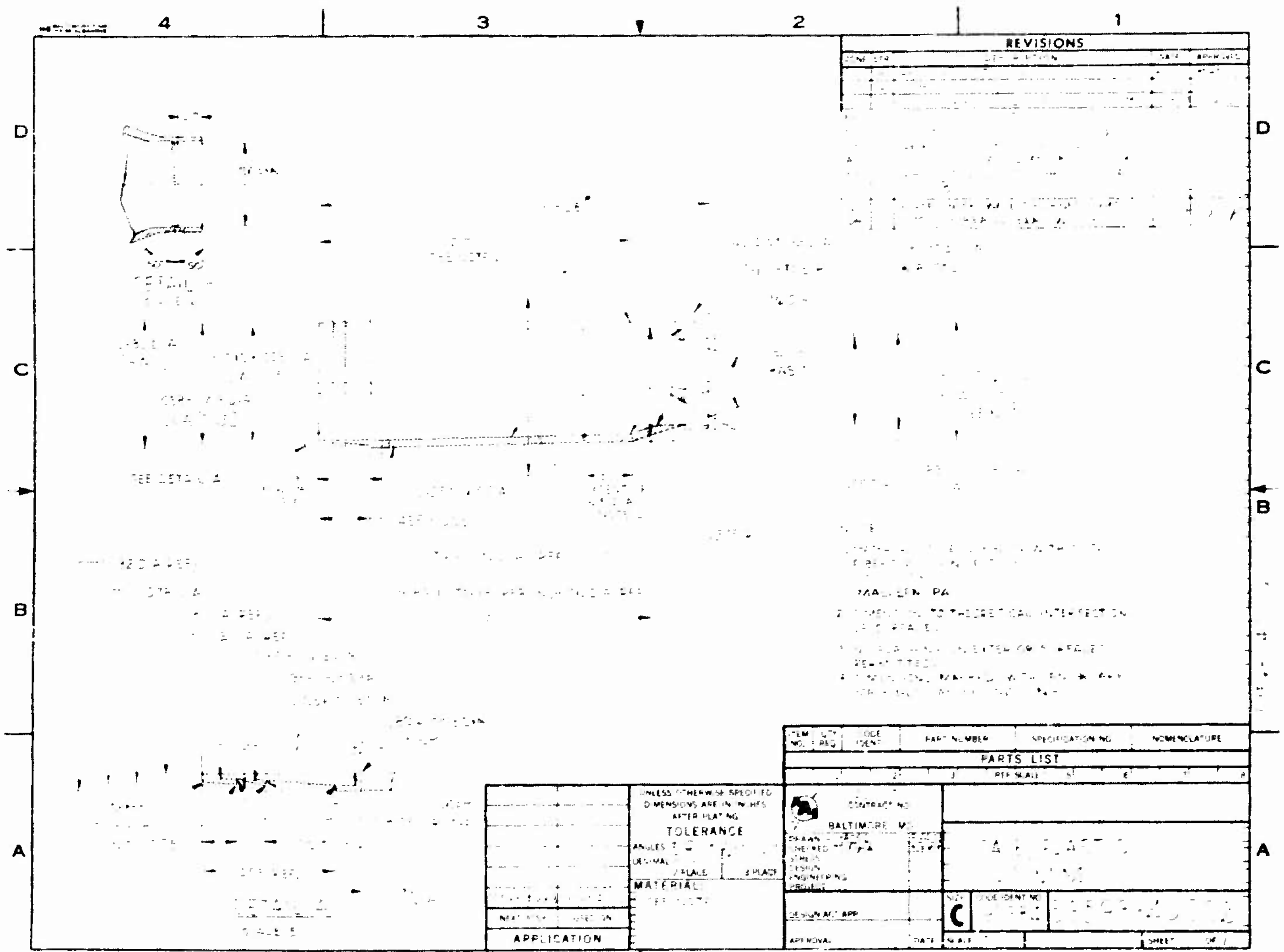
TOLERANCE
MATERIAL
APPLICATION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SEE DETAIL A
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QTY REQ
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PART NUMBER
SPECIFICATION NO.
NOMENCLATURE
CONTRACT NO.
BALTIMORE, MD
DRAWN
CHECKED
DESIGN
ENGINEERING
PROJECT
DESIGN ACT APP
APPROVAL
DATE
SIZE
C
CODE IDENT NO.
SCALE
SHEET
UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
AFTER PLATING
TOLERANCE
ANGLES
DECIMAL
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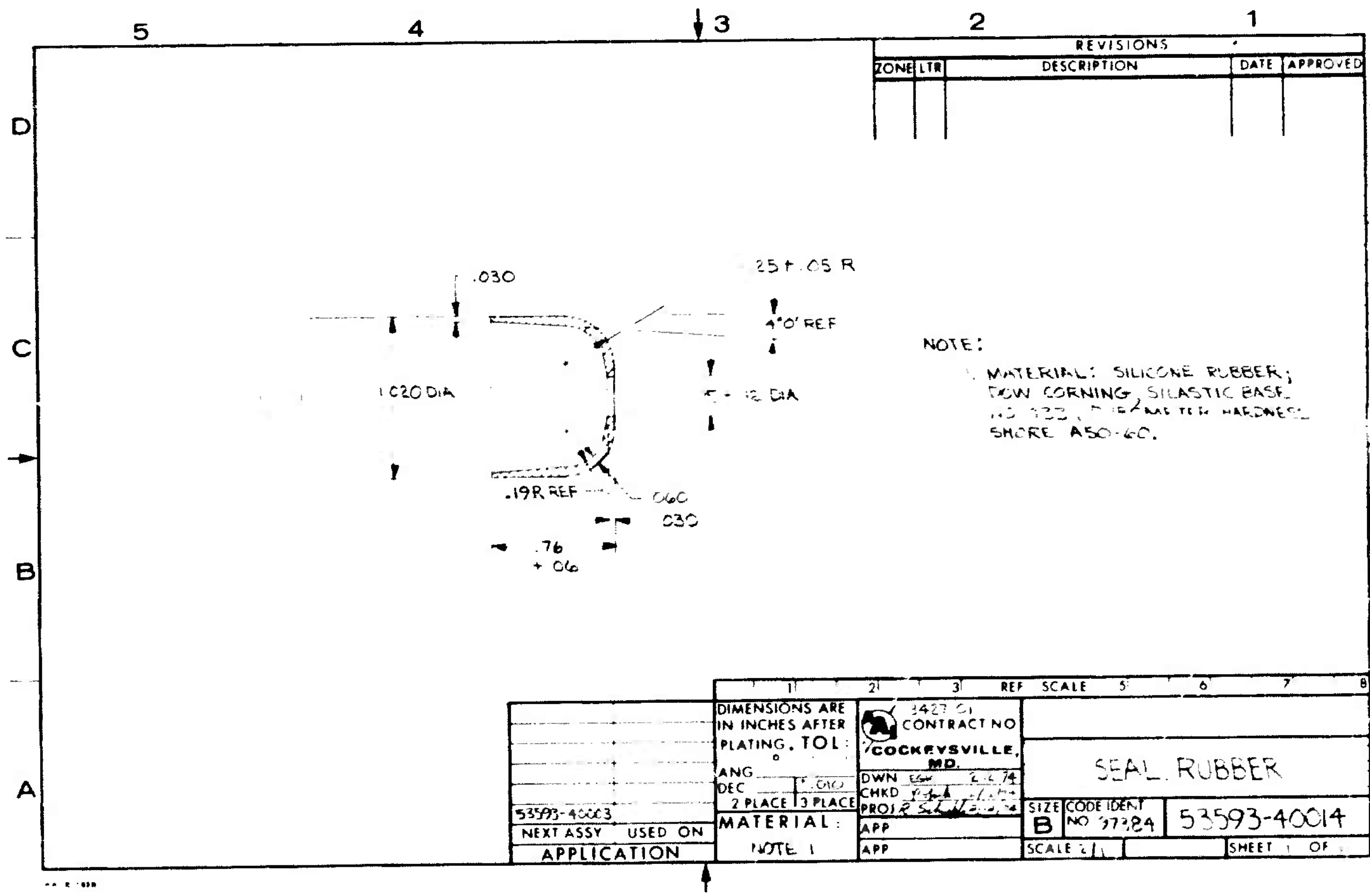
3 PLACE
MATERIAL
NEXT ASSY
USED ON
APPLICATION
1
2
3
4
A
B
C
D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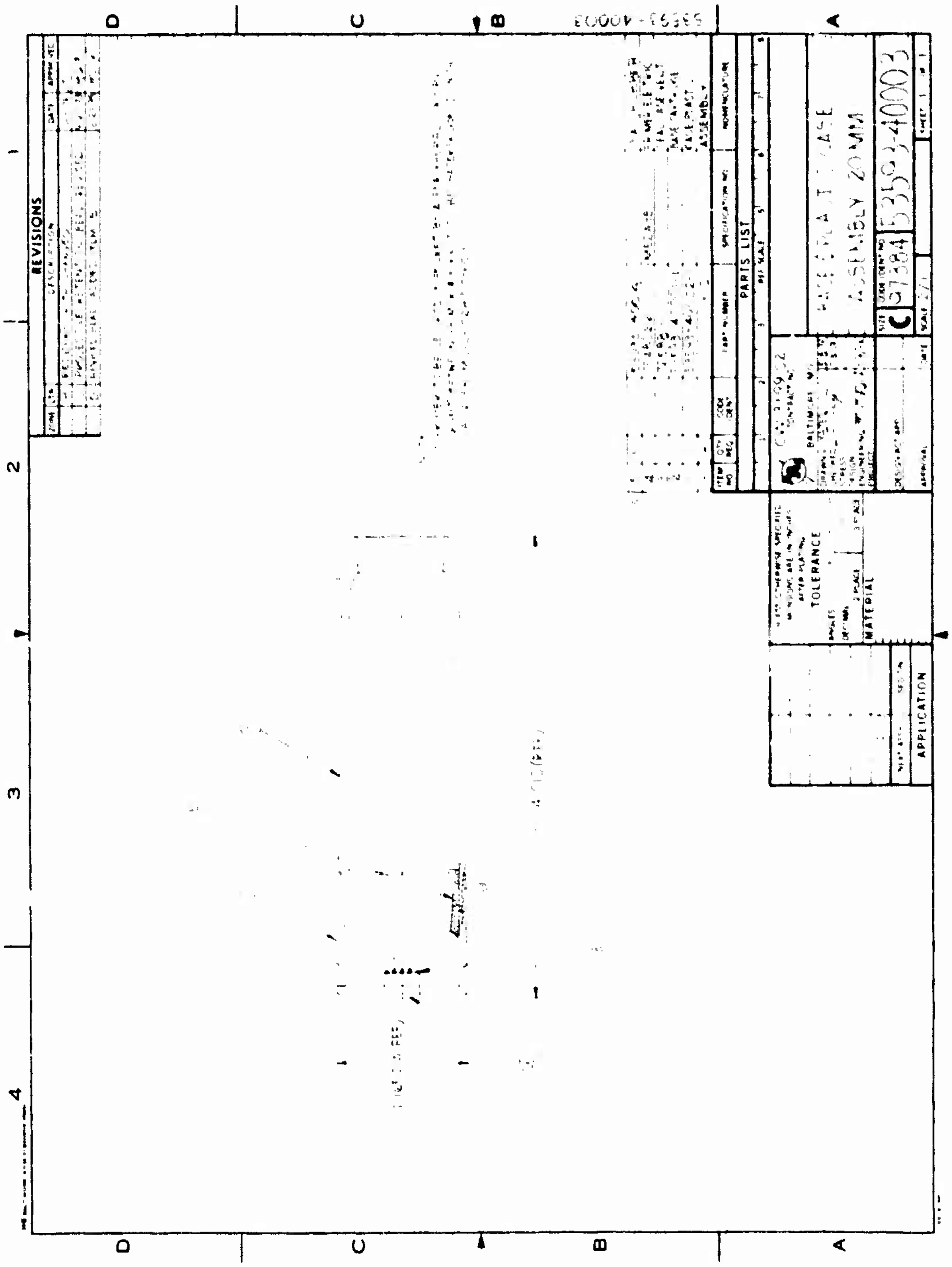
ZONE LTR DESCRIPTION DATE APPROVED
.030
1.020 DIA
.25 ±.05 R
4°0' REF
.19R REF
.060
.030
.76 ±.06
DIA
NOTE:
1. MATERIAL: SILICONE RUBBER; DOW CORNING SILASTIC BASE SHORE A50-60.
DIMENSIONS ARE IN INCHES AFTER PLATING. TOL:
ANG
DEC
2 PLACE 3 PLACE
±.010
MATERIAL:
NOTE 1
CONTRACT NO
COCKEYSVILLE, MD.
DWN
CHKD
PROJ
APP
APP
SEAL, RUBBER
SIZE B
CODE IDENT NO 97384
53593-40014
SCALE
SHEET 1 OF
53593-40003
NEXT ASSY USED ON
APPLICATION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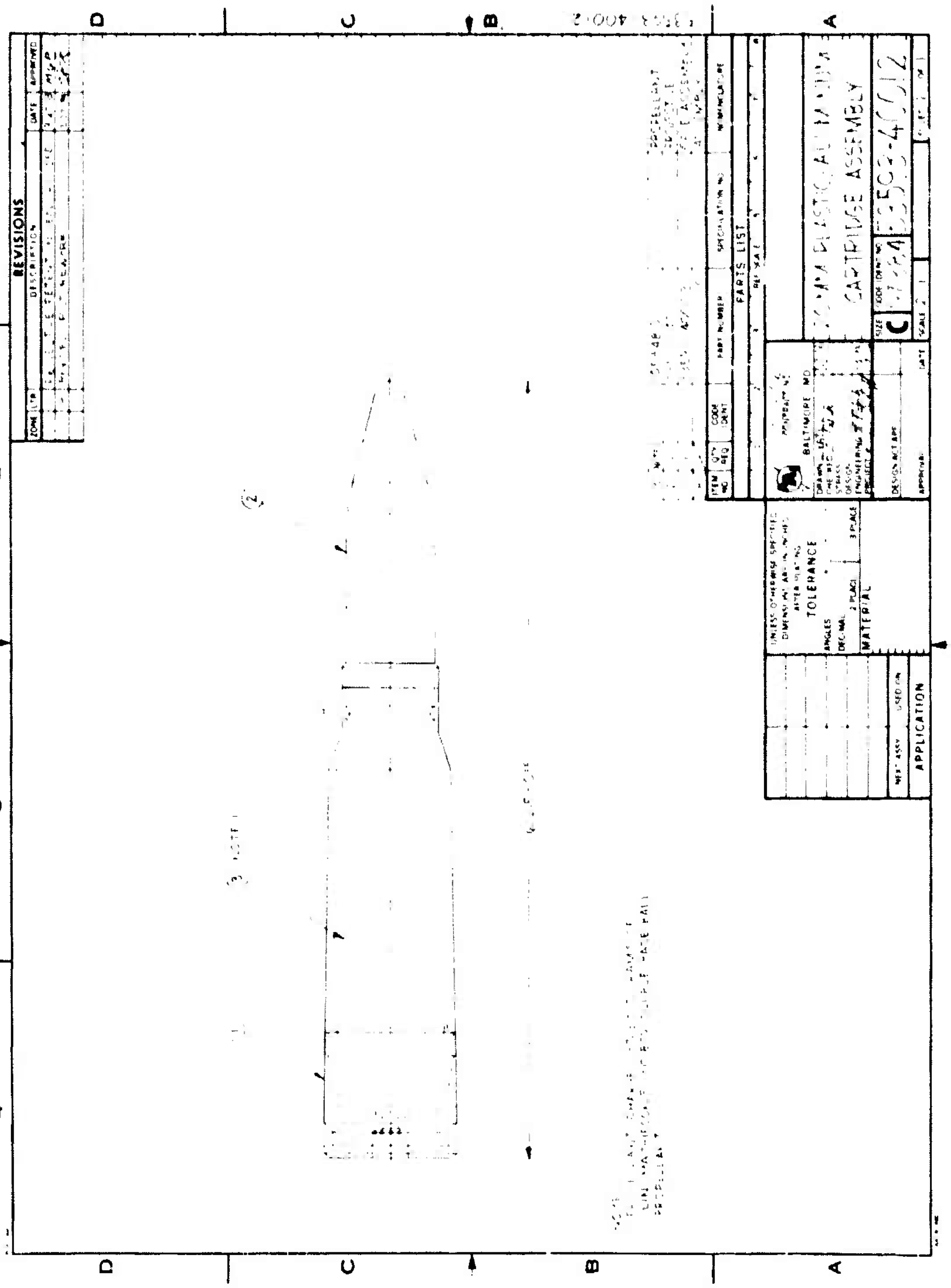
53593-40003
BALTIMORE, MD.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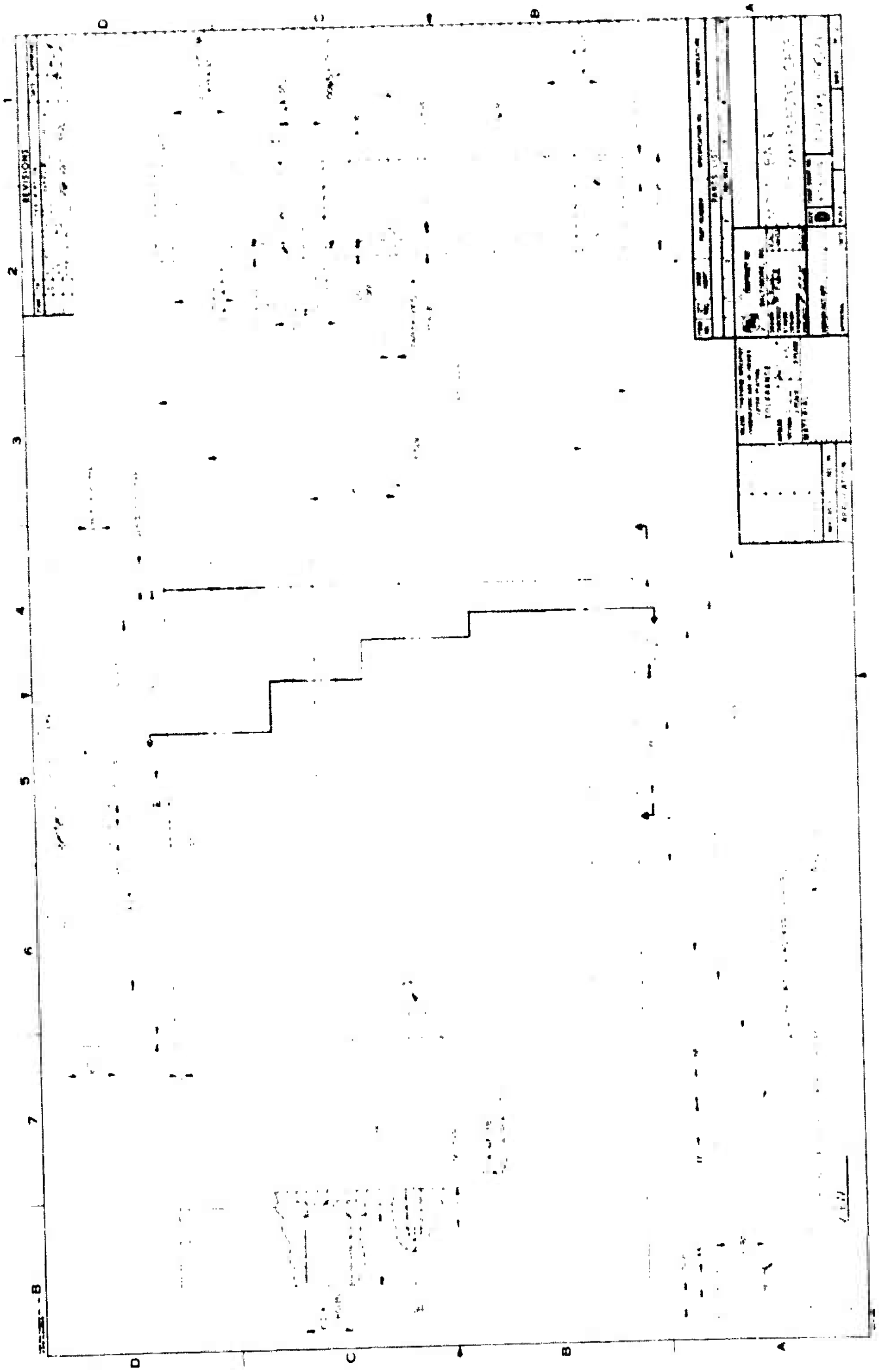
BALTIMORE, MD
CARTRIDGE ASSEMBLY
TOLERANCE
MATERIAL
APPLICATION

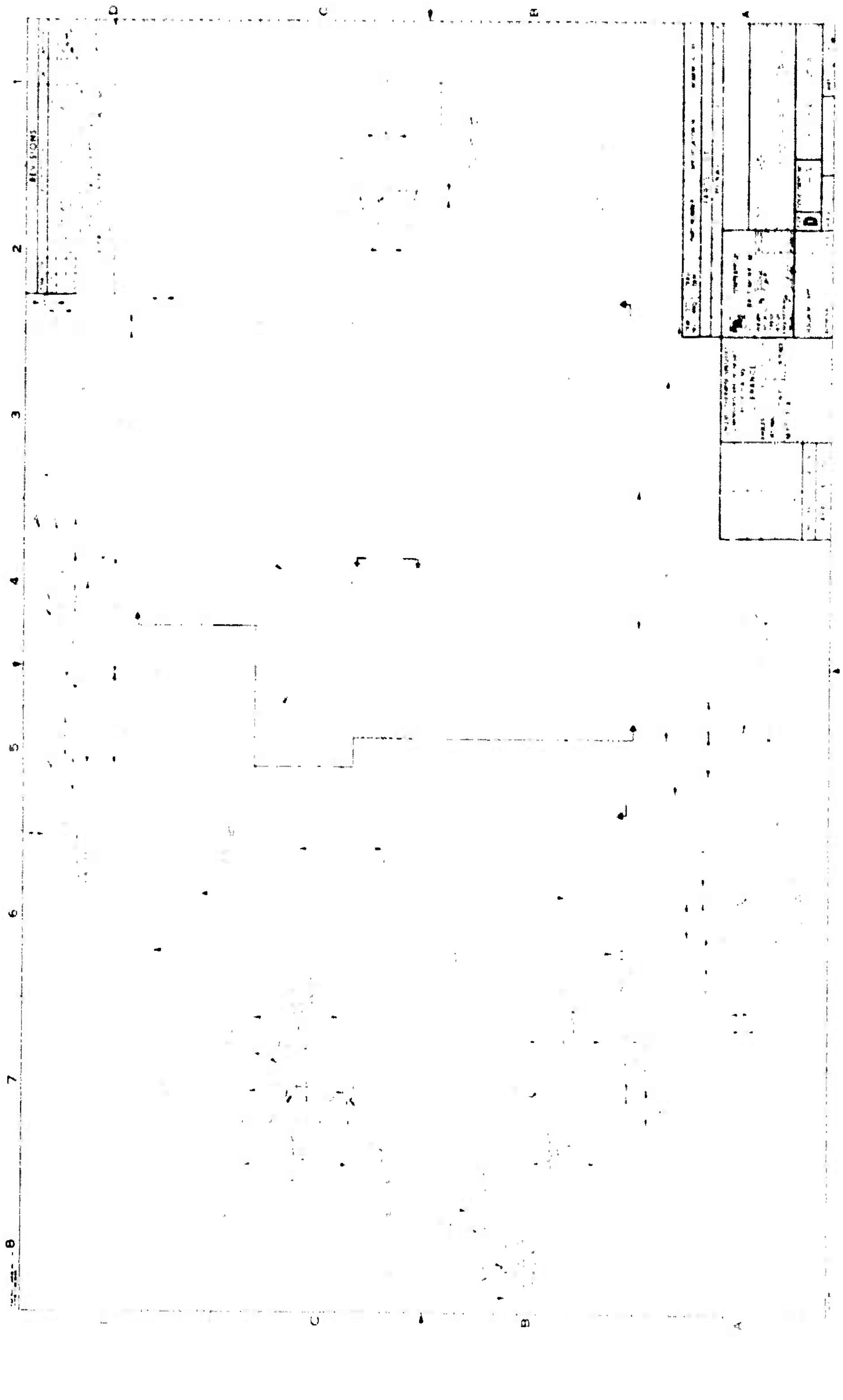
APPENDIX II

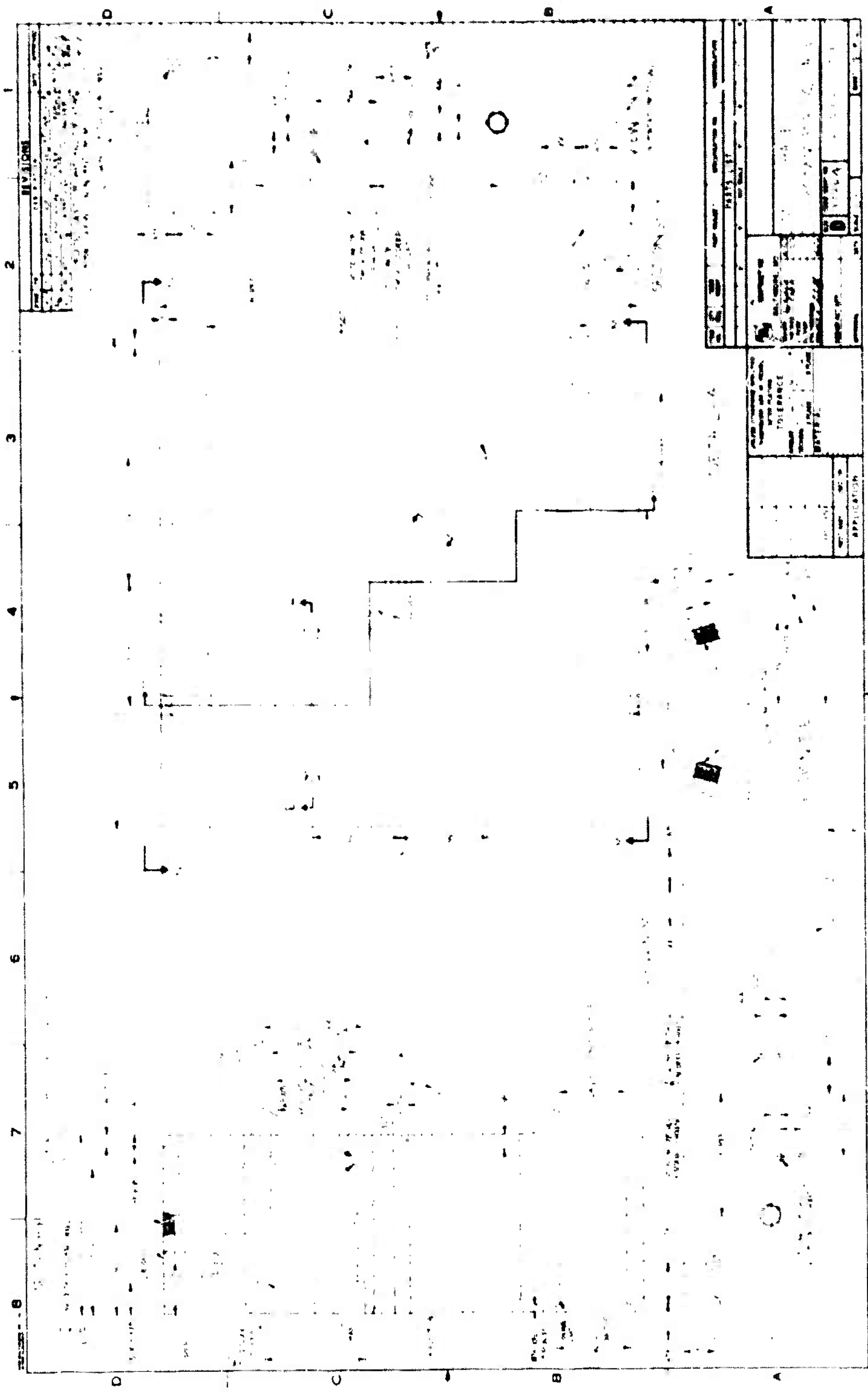
PRODUCTION MOLD DRAWINGS

This appendix consists of the following production mold drawings:

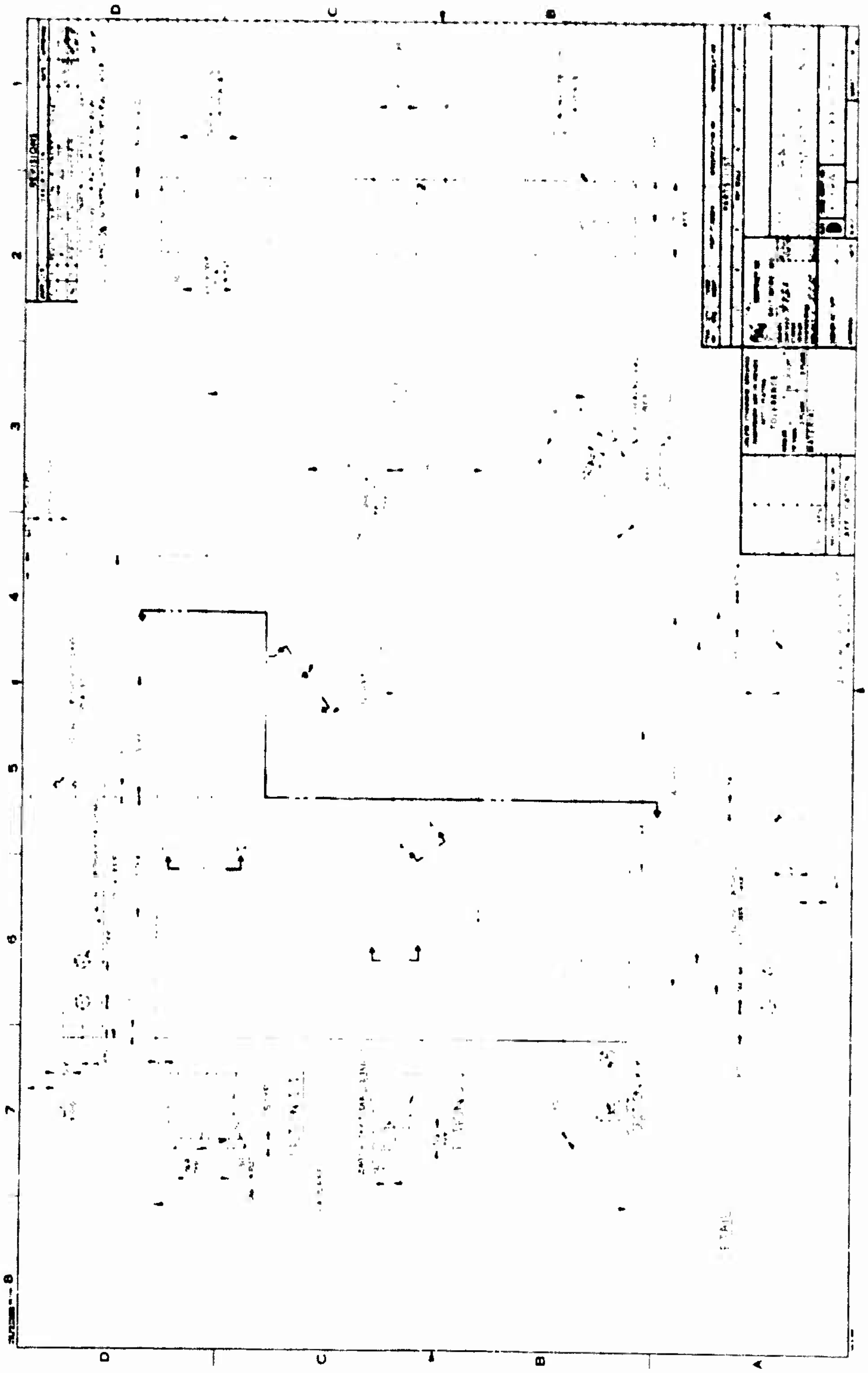
53593-10031	20mm Mold Base
53593-10032	20mm Mold Core
53593-10033	20mm Mold Cavity
53593-10034	Segments
53593-10035	Cavity Retainer
53593-10036	20mm Mold Slide
53593-10037	Stripper
53593-10038	Latch Release
53593-10039	Latch
53593-10040	Latch Clevis
53593-10041	Latch Stop
53593-10042	Latch Shim
53593-10043	Stop Rod
53593-10044	Stop
53593-10045	Latch Spring
53593-10046	Slide Pin
53593-10050	20mm Mold Assembly

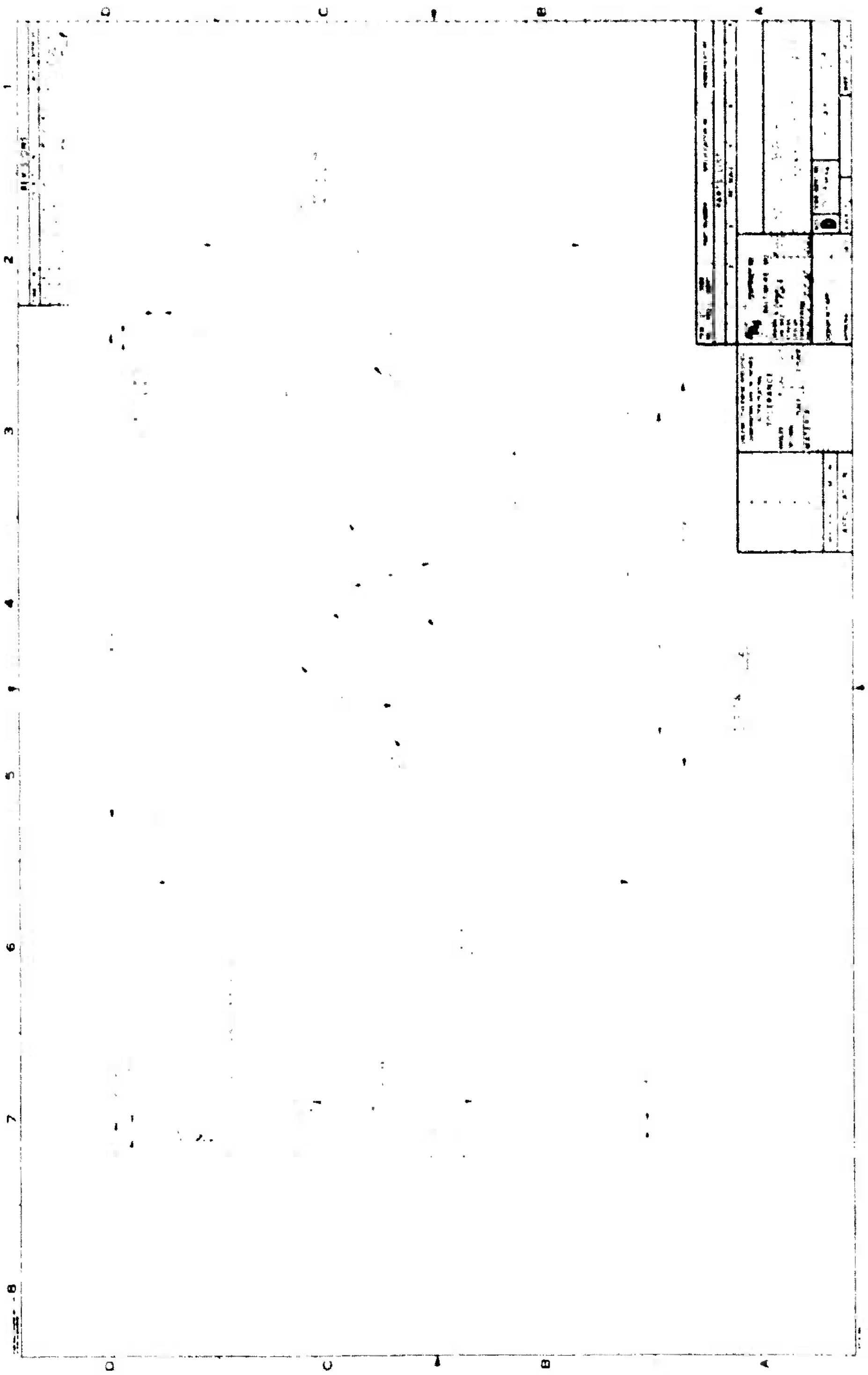


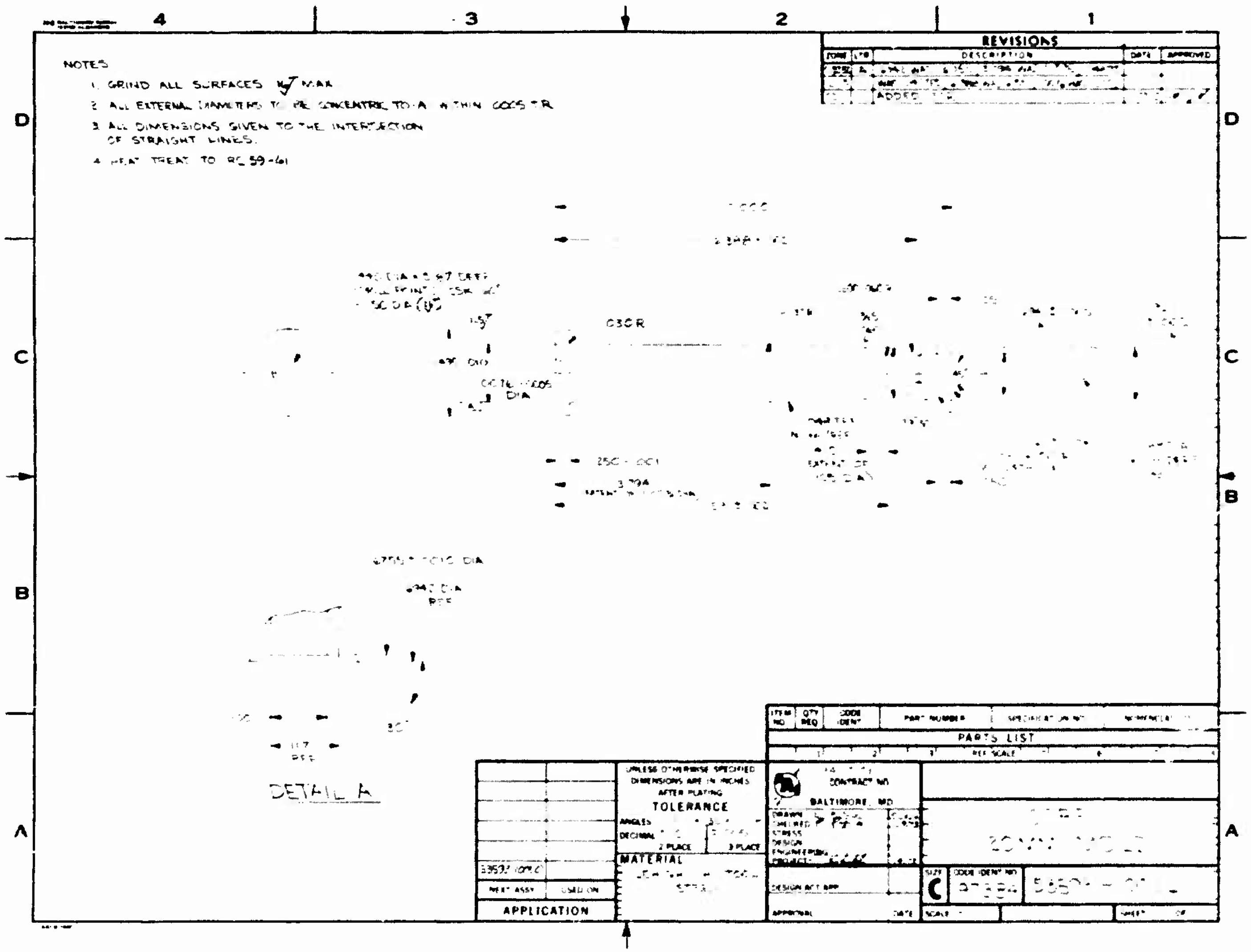




COPY AVAILABLE TO DDC DOES NOT
PERMIT FULLY LEGIBLE PRODUCTION



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2. ALL EXTERNAL DIAMETERS TO BE CONCENTRIC TO A WITHIN .0005 T.I.R.
3. ALL DIMENSIONS GIVEN TO THE INTERSECTION OF STRAIGHT LINES.
4. HEAT TREAT TO RC 59-61
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DETAIL A
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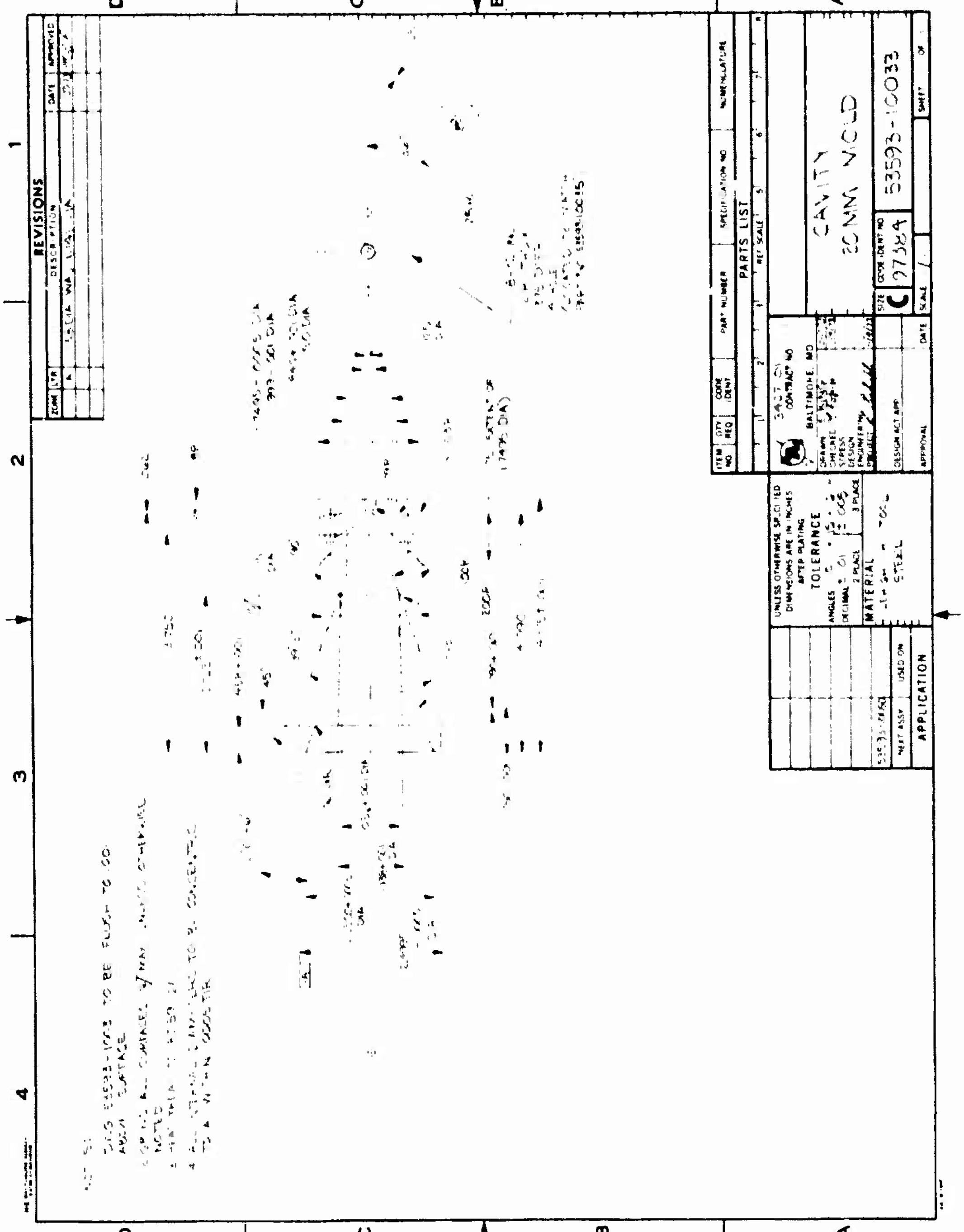
BALTIMORE, MD
TOLERANCE
MATERIAL
APPLICATION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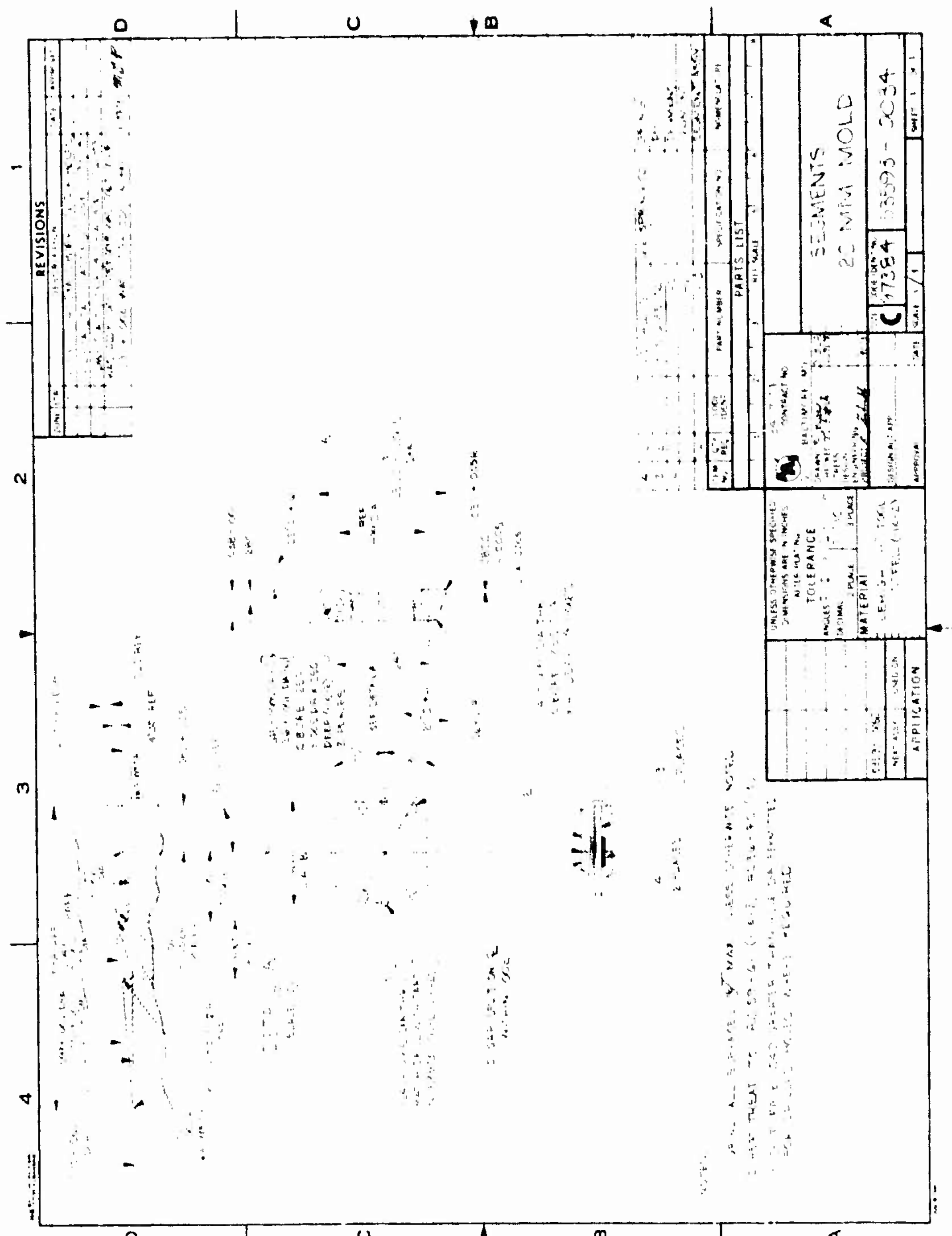
APPLICATION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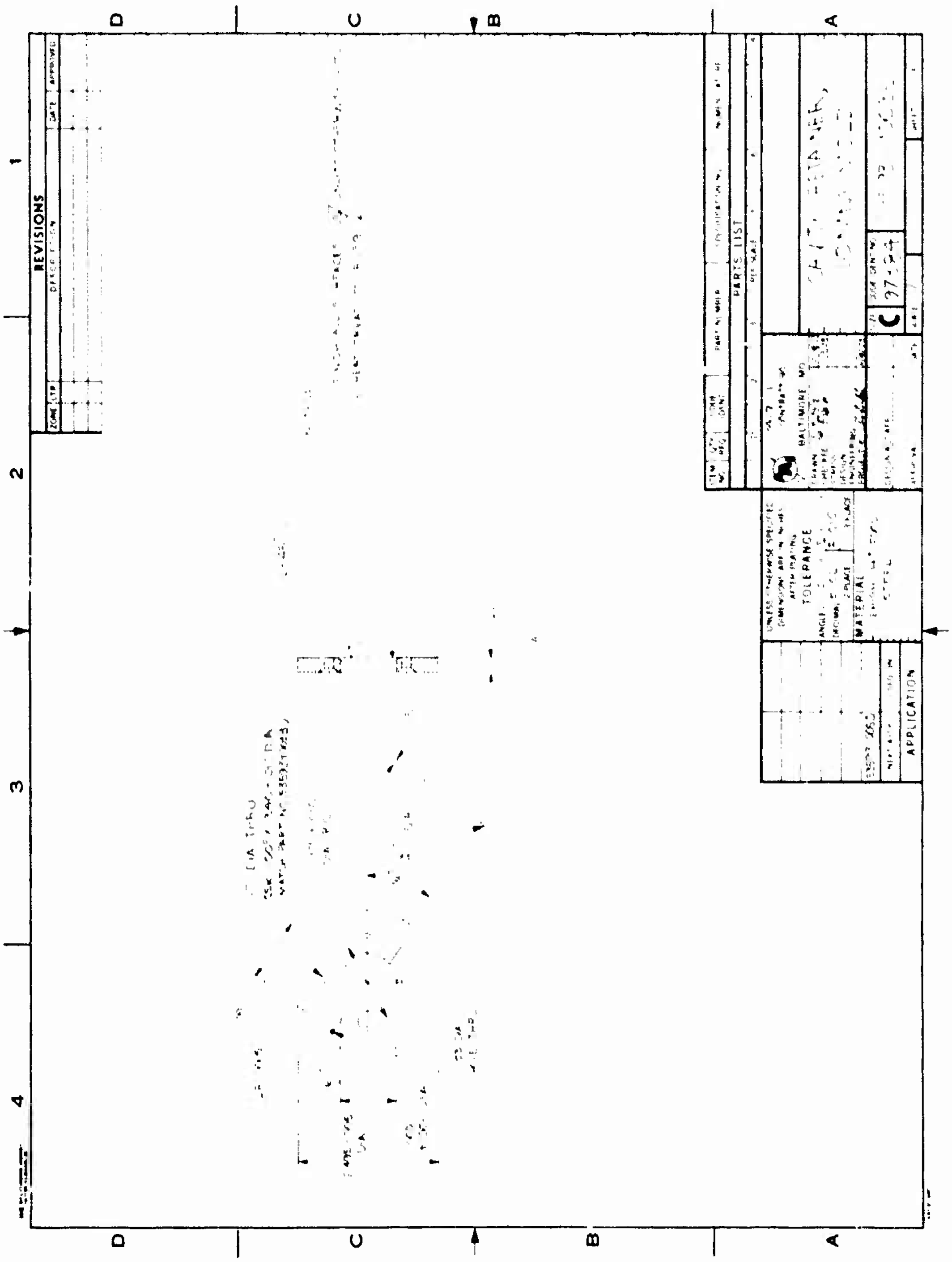
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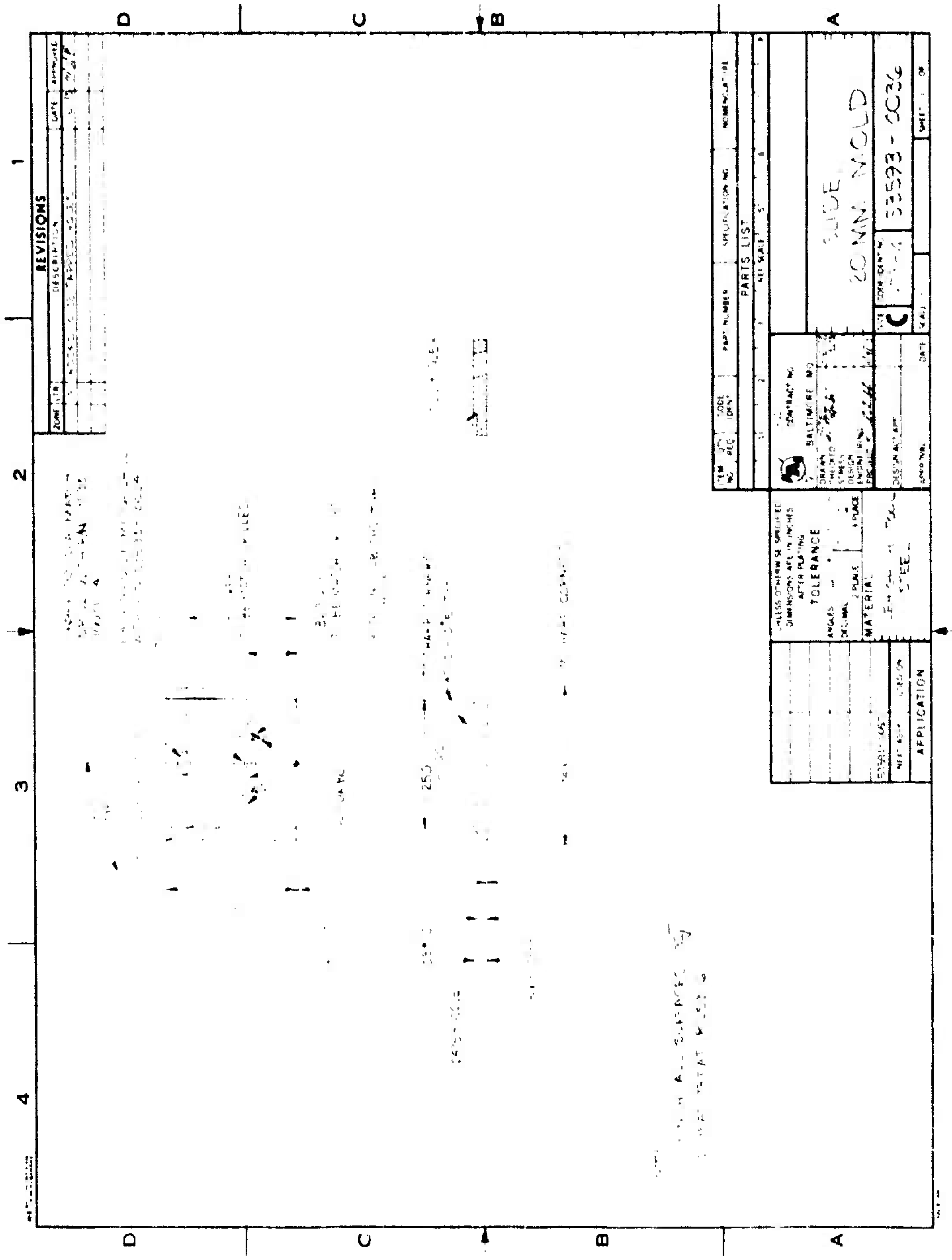
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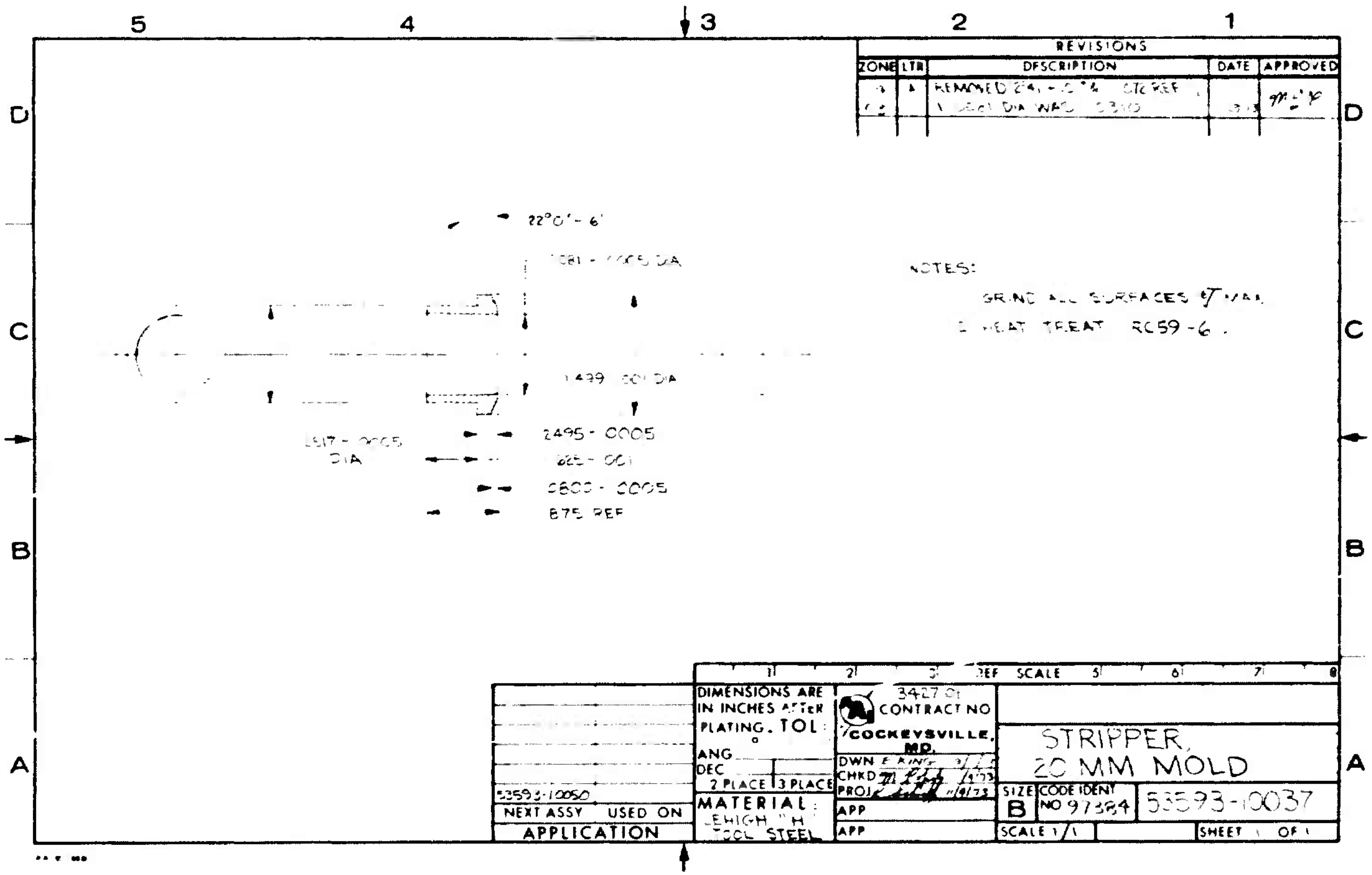

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DIA
2495 - .0005
2517 - .0005
DIA
2600 - .0005
875 REF
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MATERIAL:
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COCKEYSVILLE, MD.
DWN
CHKD
PROJ
APP
APP
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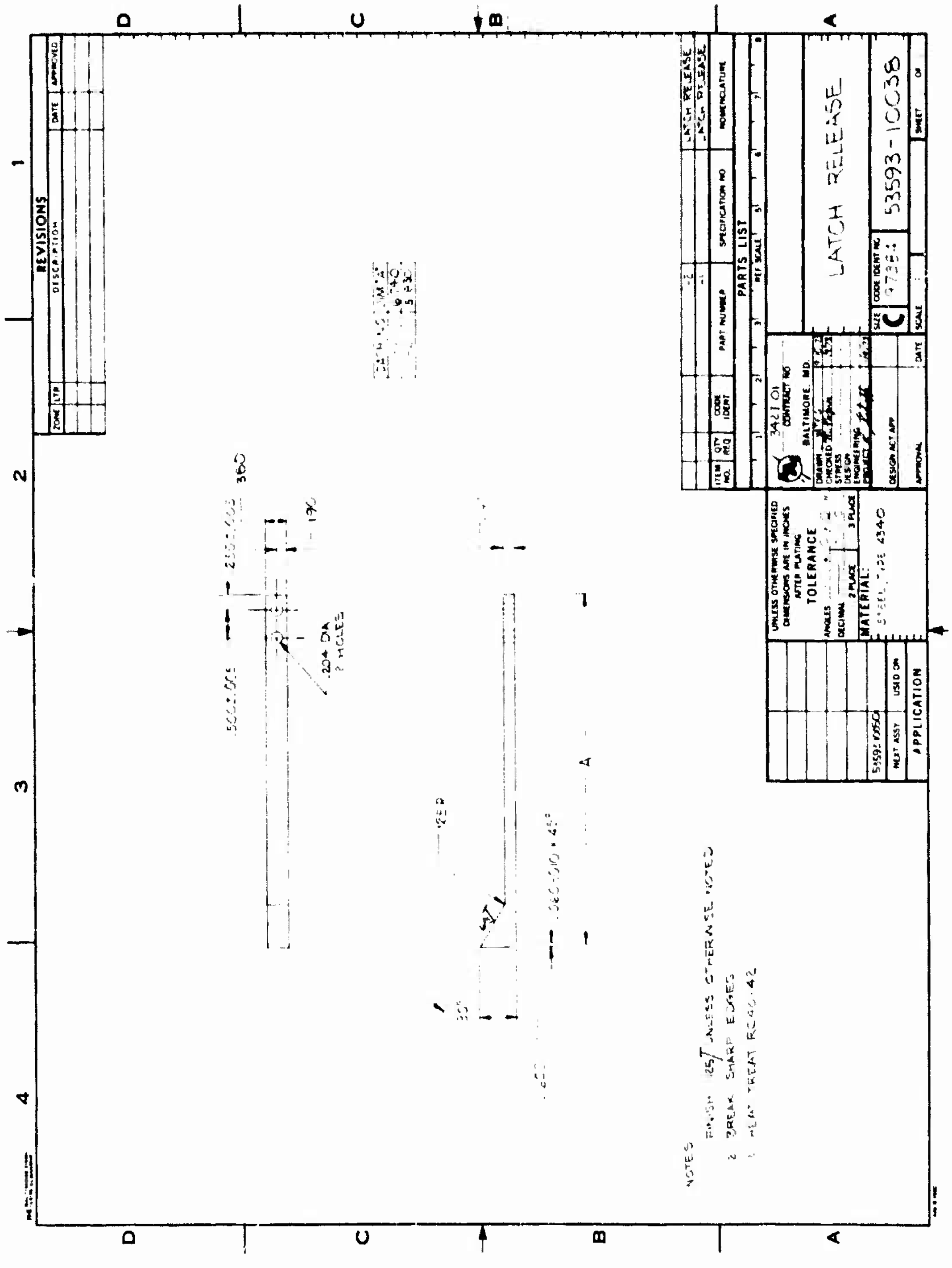
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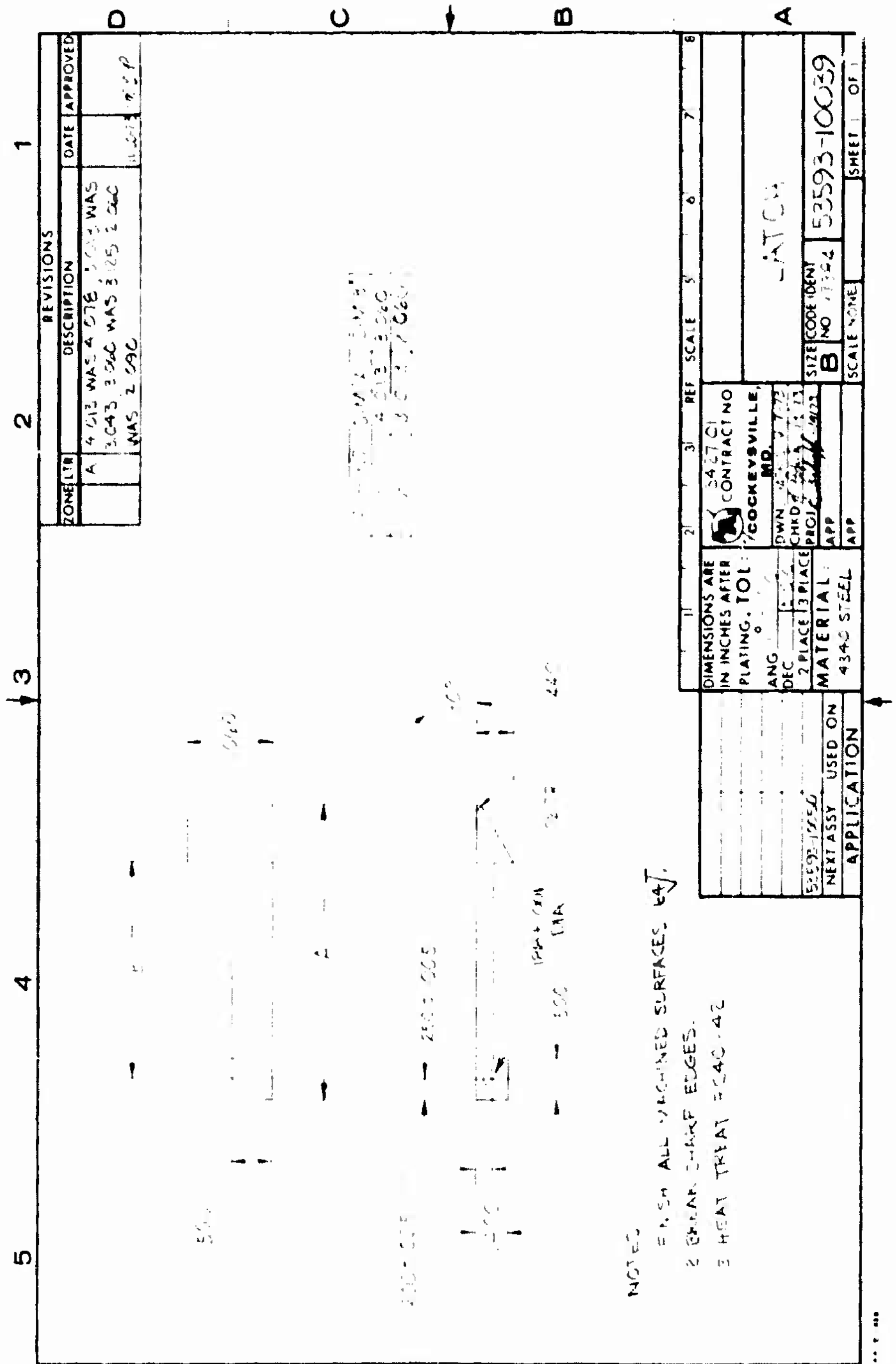
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CHKD
PROJ
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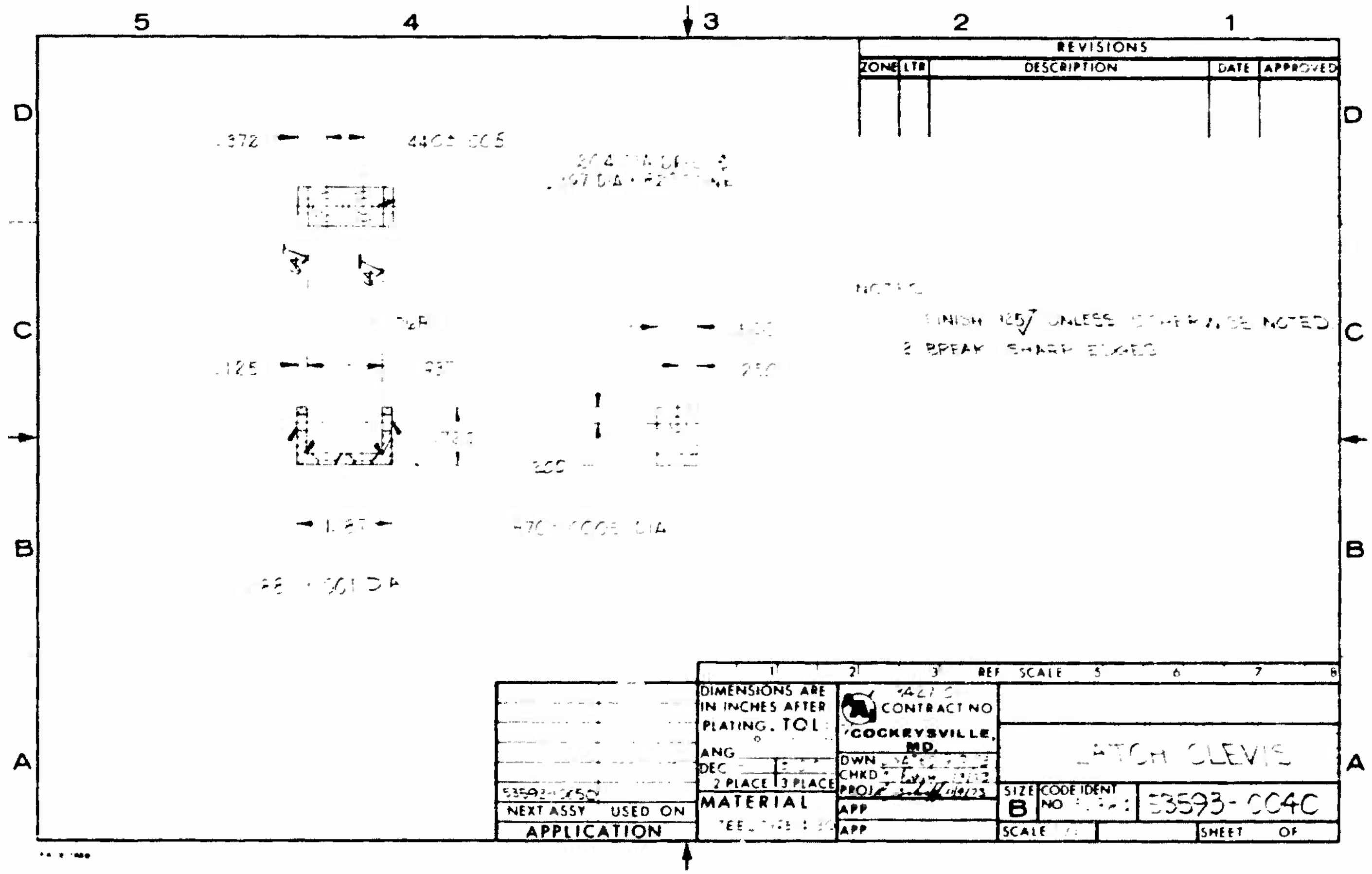

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CHKD
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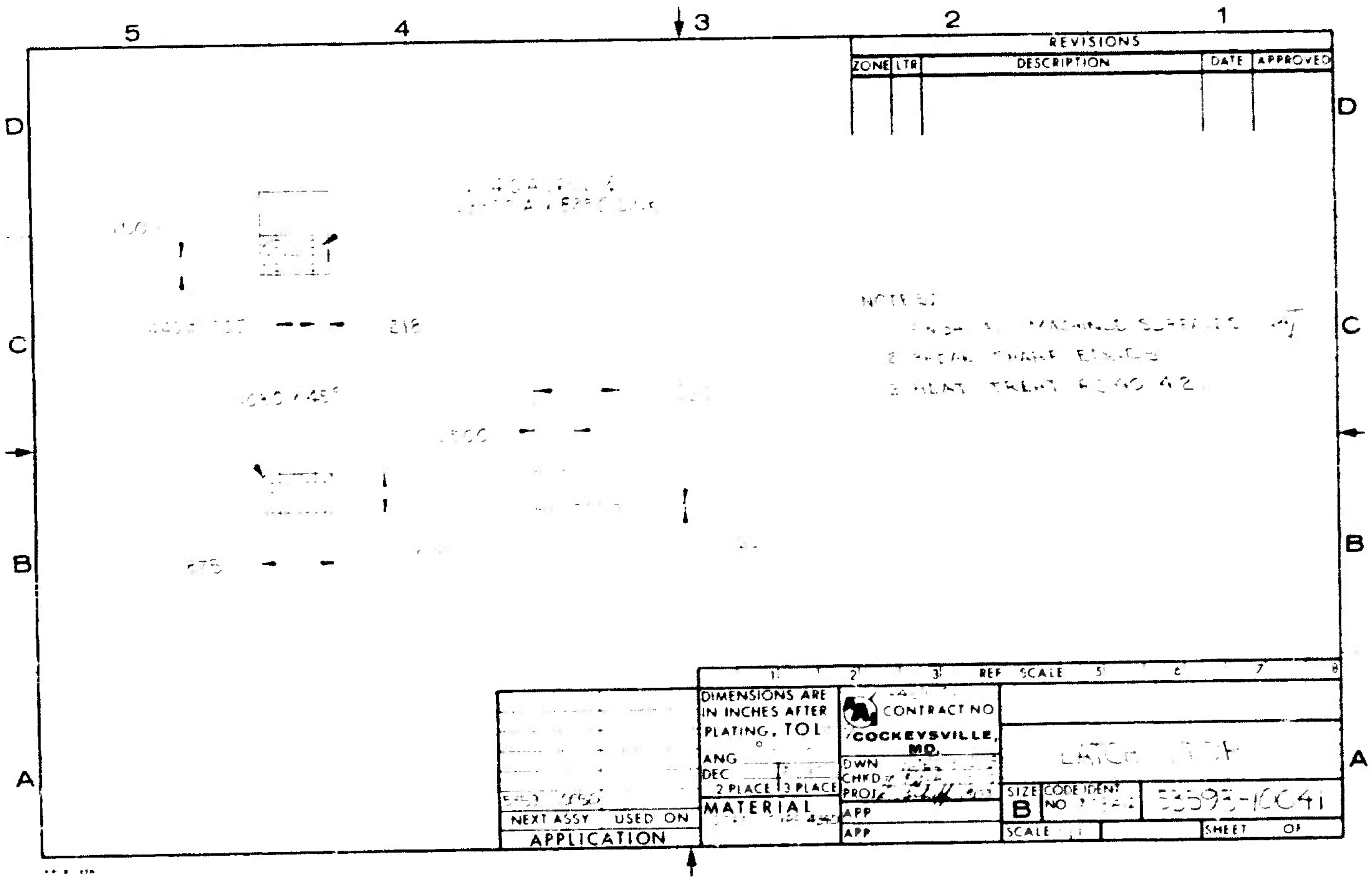
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NEXT ASSY
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APPLICATION
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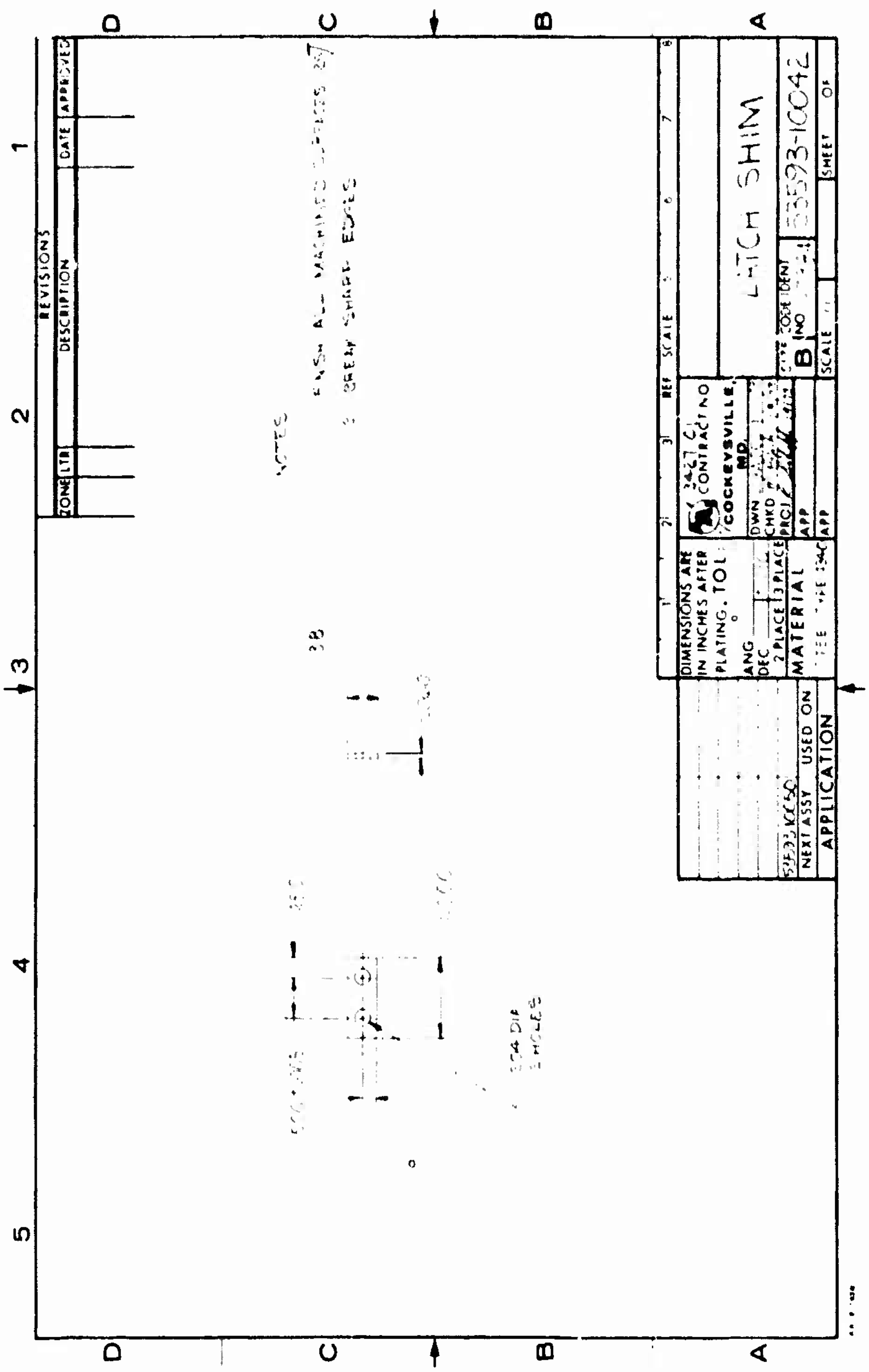
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APPLICATION
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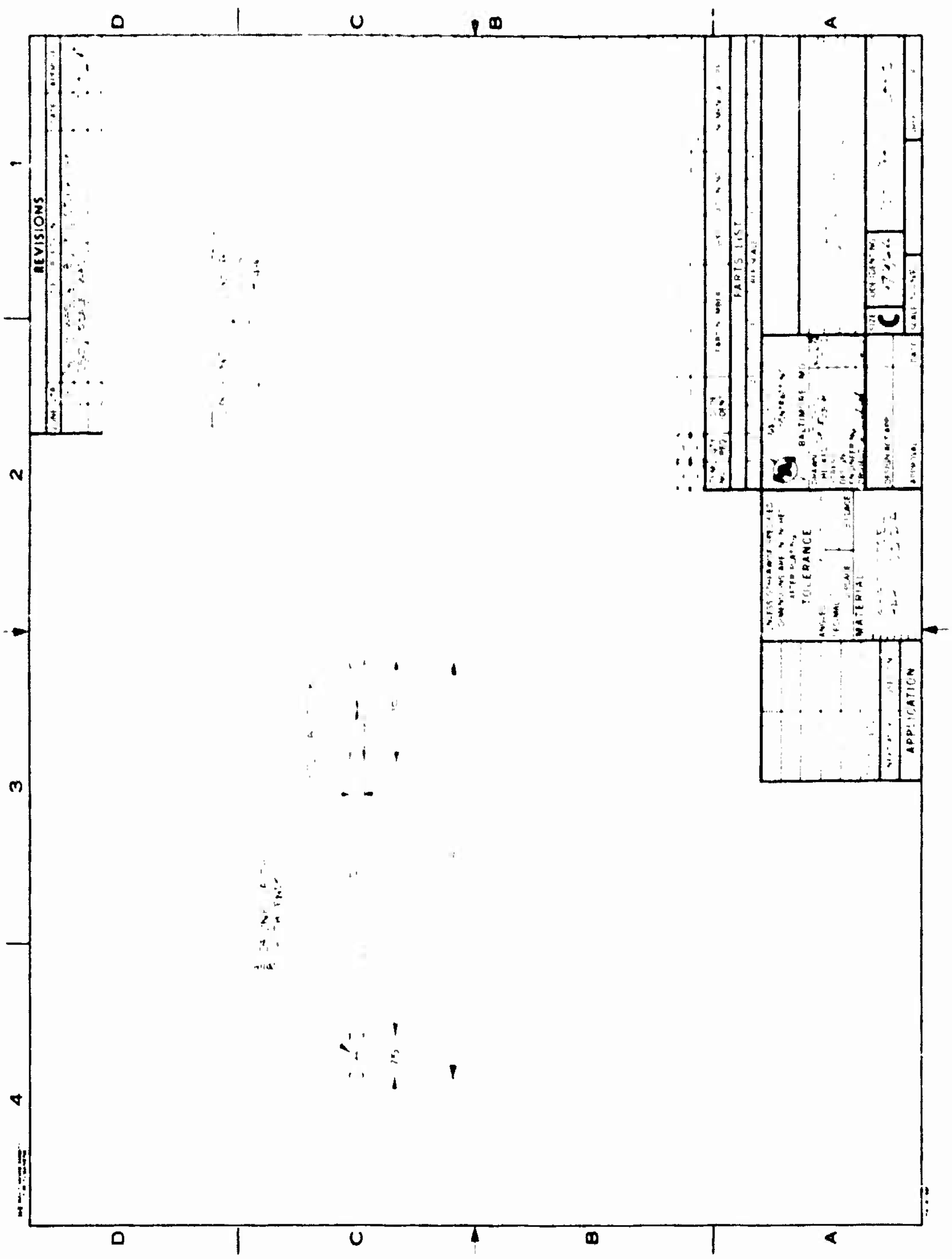
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TOLERANCE
MATERIAL
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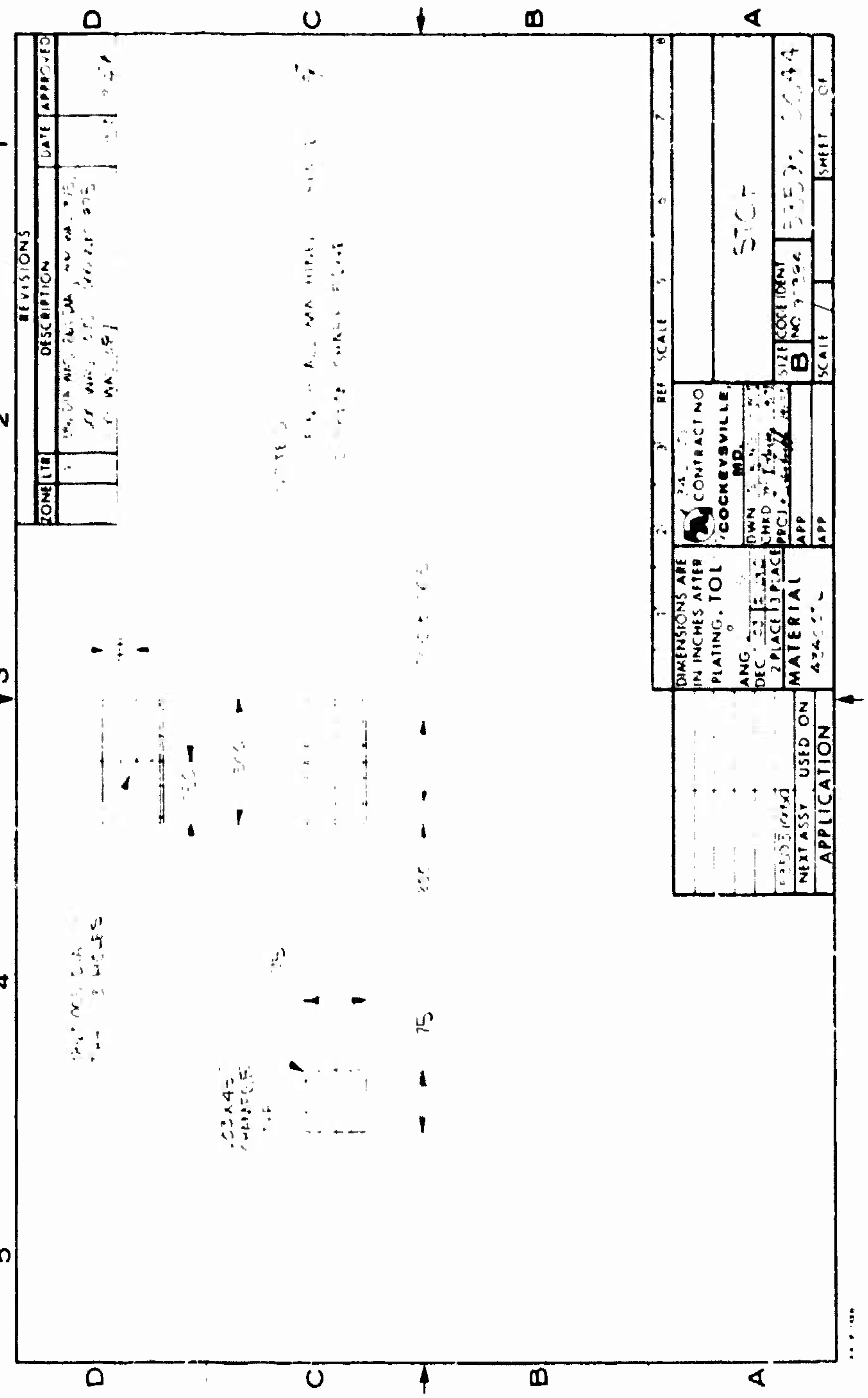
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SIZE
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OF
NEXT ASSY
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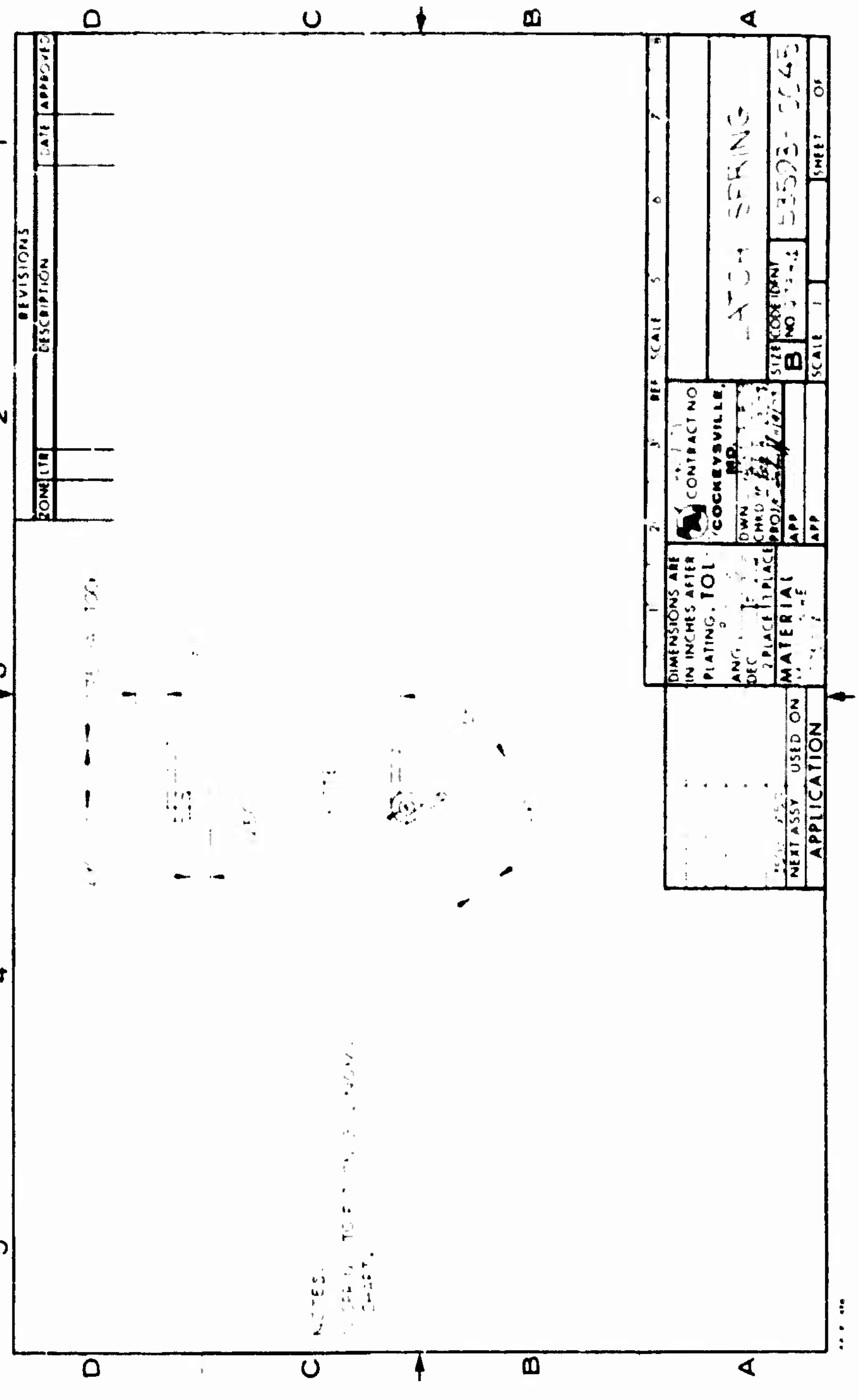
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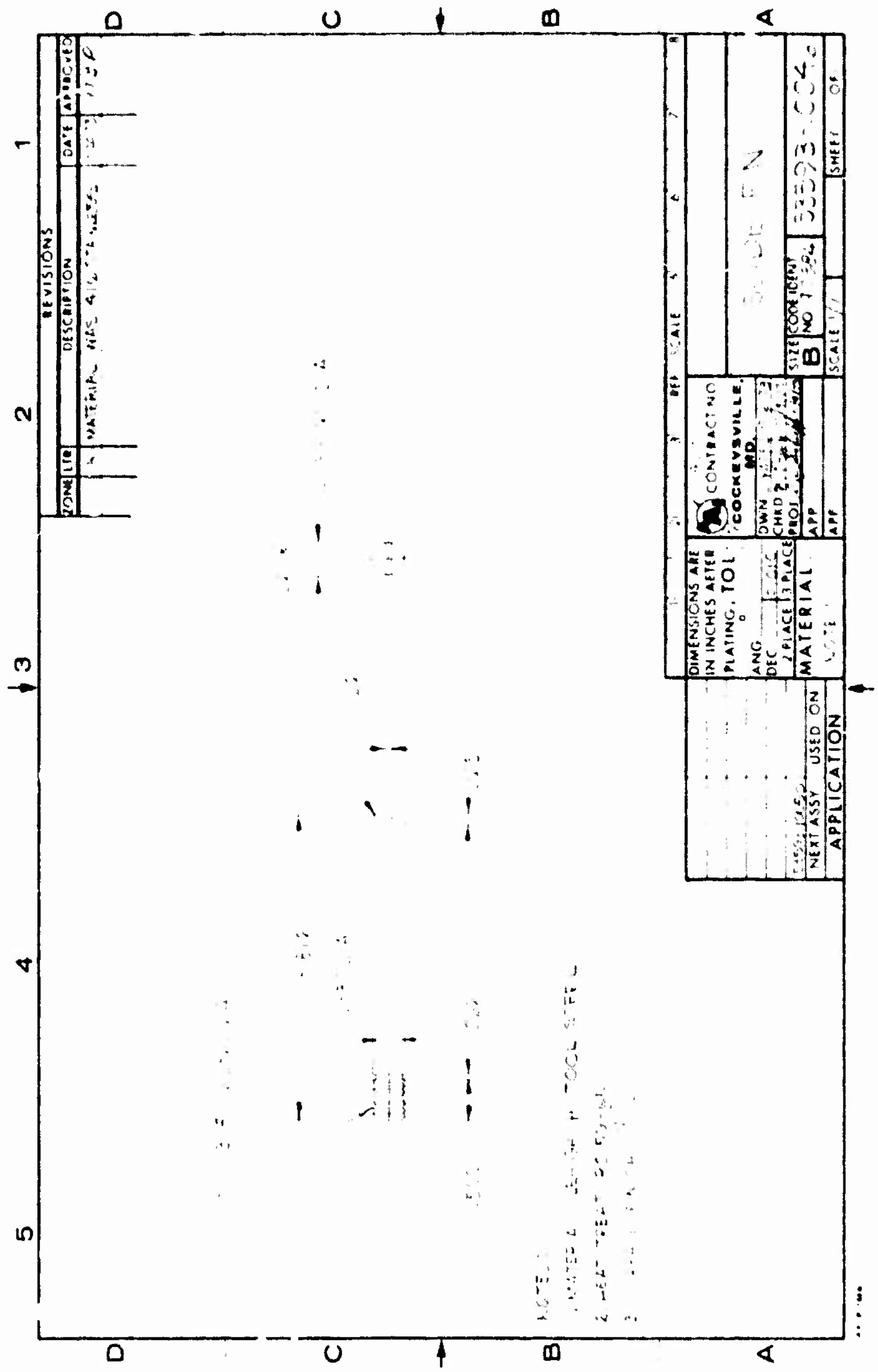
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DEC
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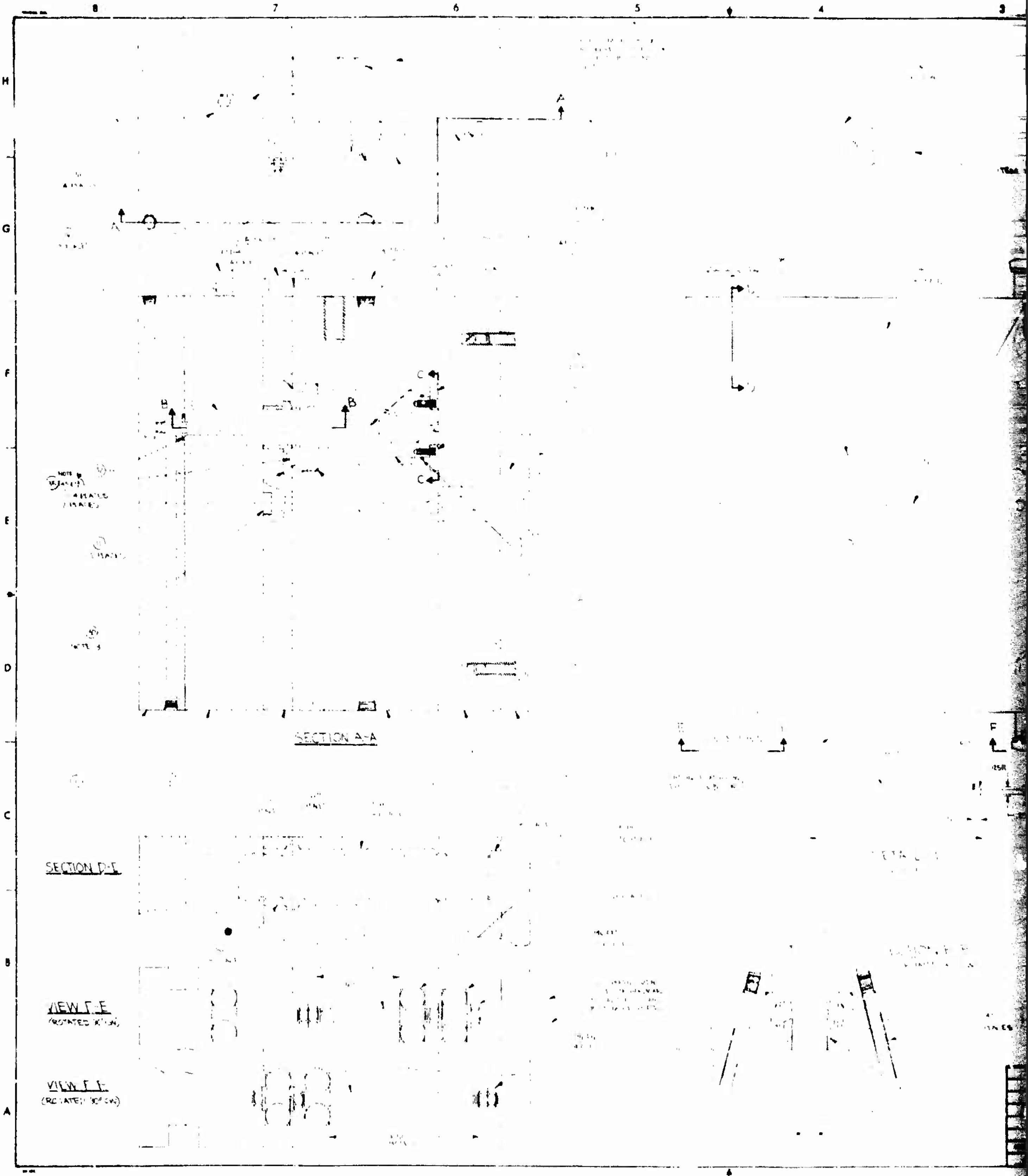
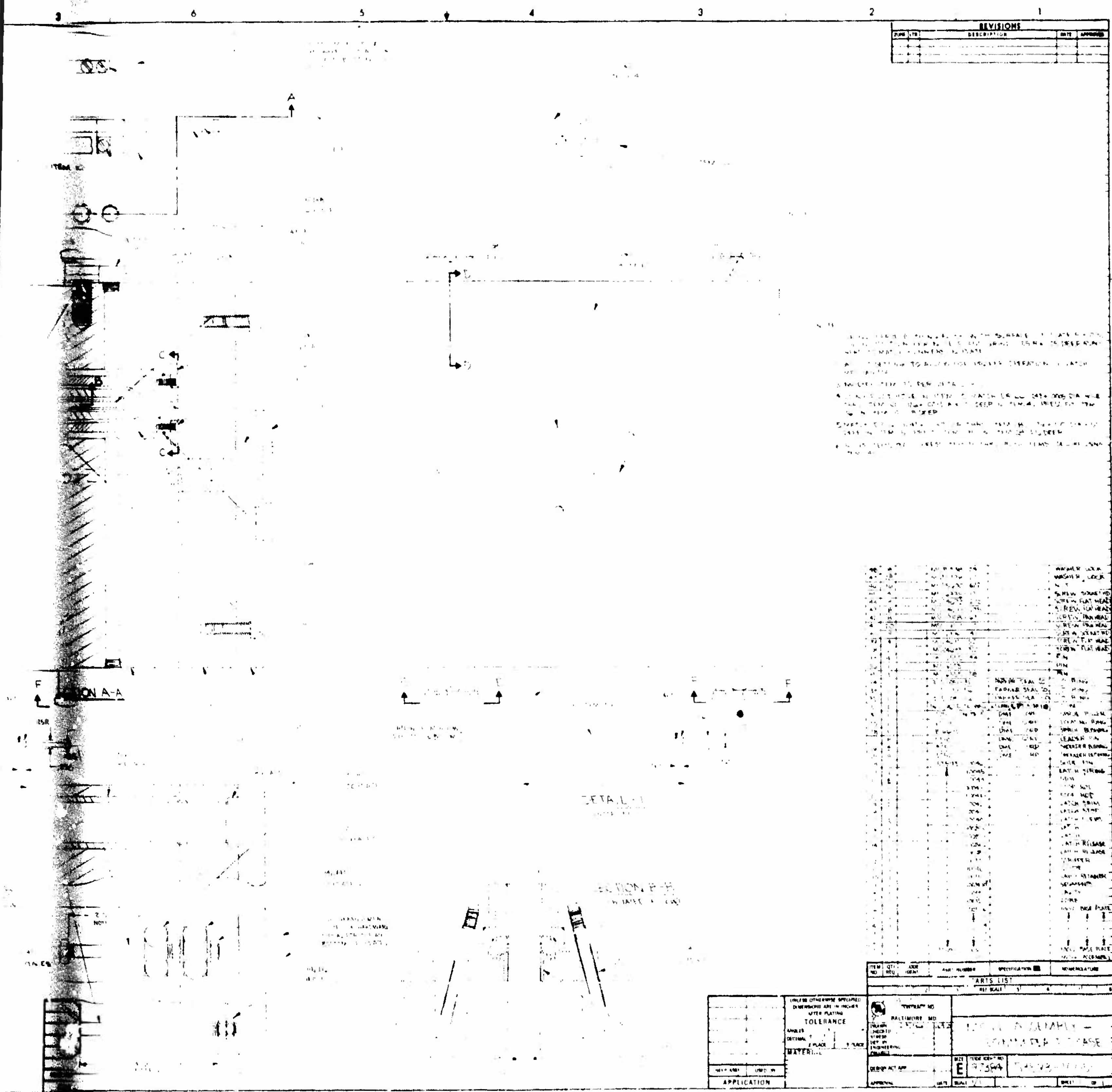
3 PLACE
CONTRACT NO
COCKEYSVILLE, MD.
DWN
CHKD
PROJ
APP
MATERIAL
NEXT ASSY
USED ON
APPLICATION
SIZE
B
CODE IDENT NO
SCALE
SHEET
OF



SECTION A-A
SECTION D-E
VIEW E-E
VIEW F-F



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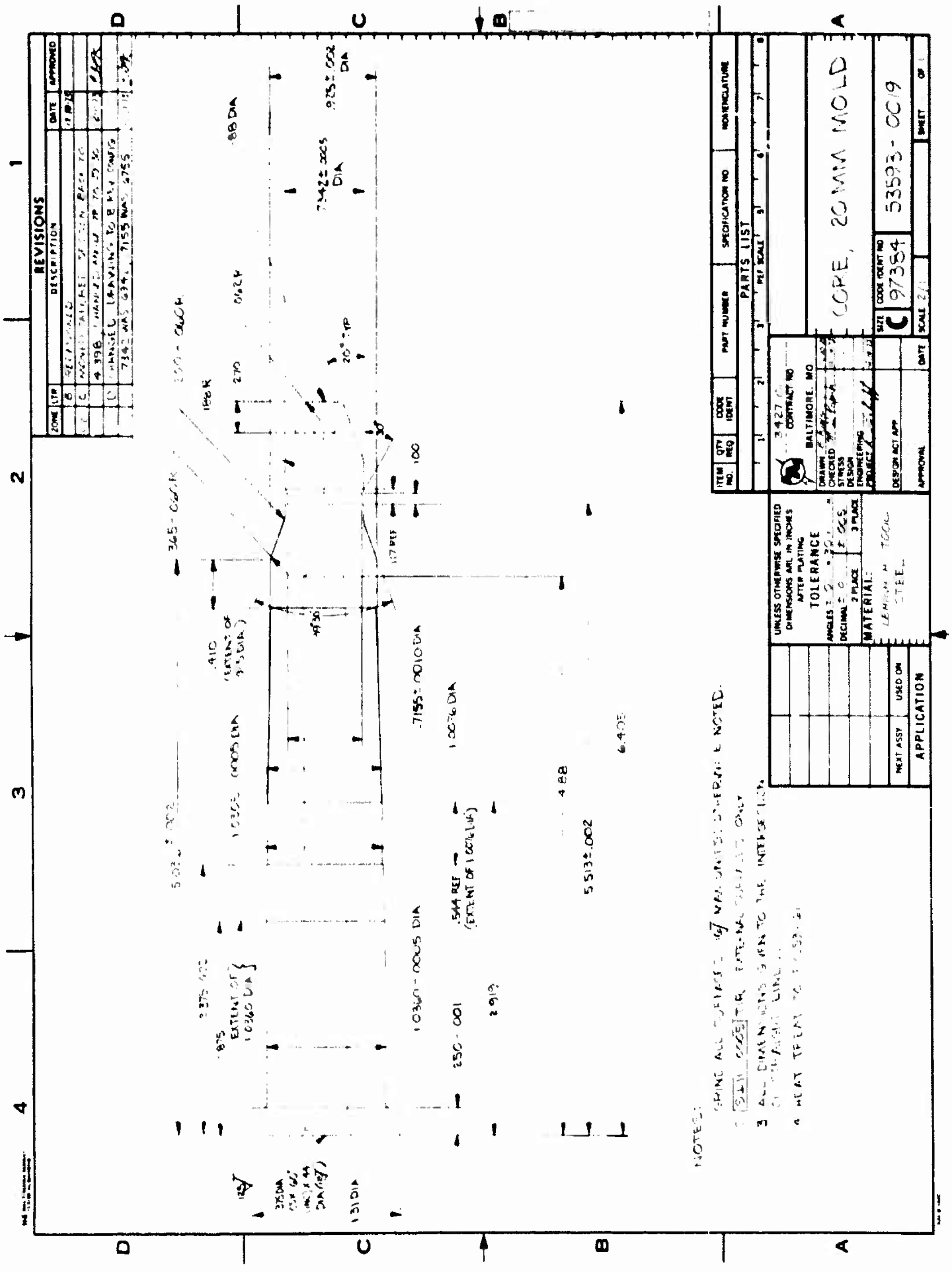
APPENDIX III

DEVELOPMENT CASE MOLD DRAWINGS

This appendix consists of the following development case mold drawings:

53593-10019	Core
53593-10020	Segments
53593-10021	Inlet
53593-10022	Cavity
53593-10023	Stripper
53593-10025	Mold Assembly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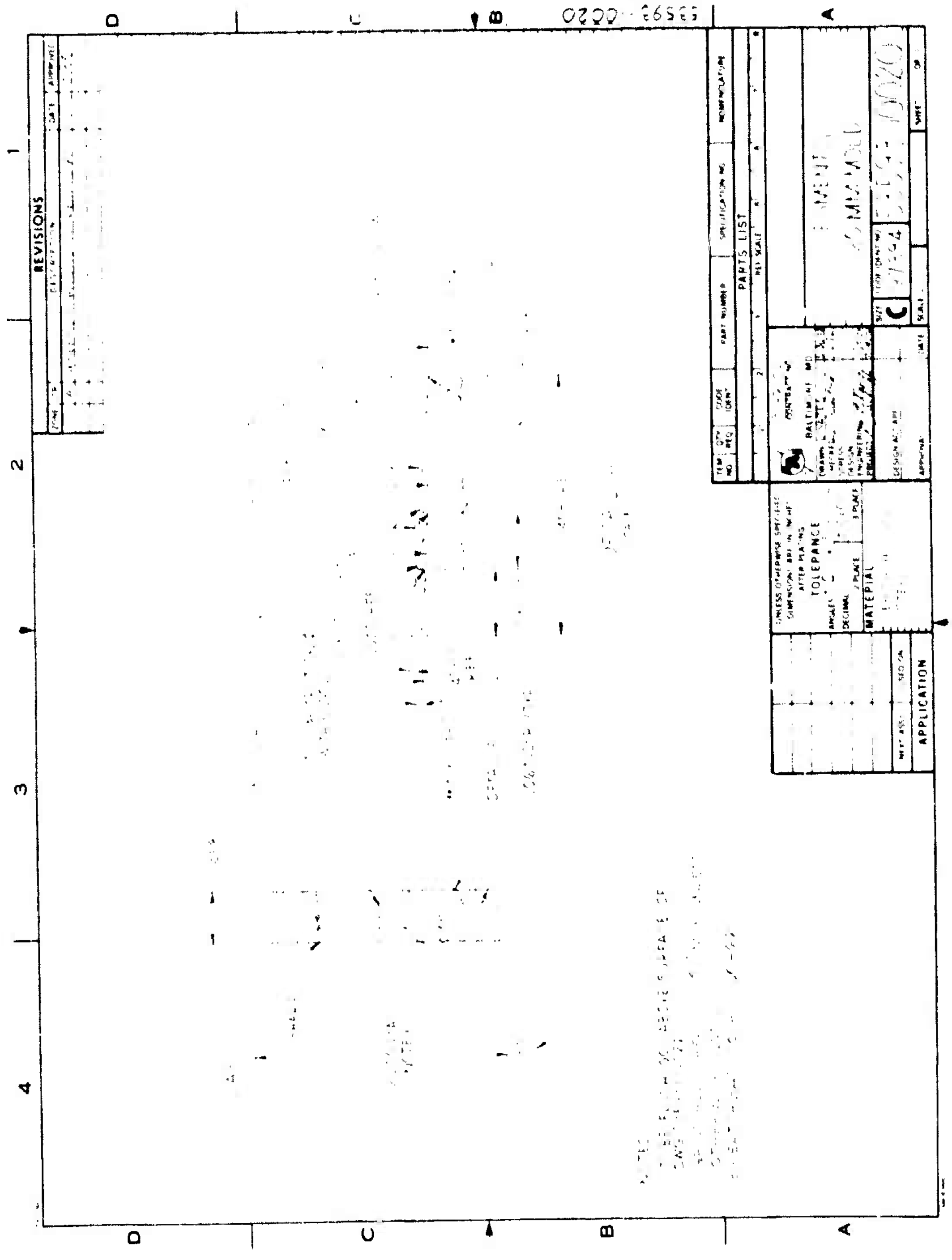
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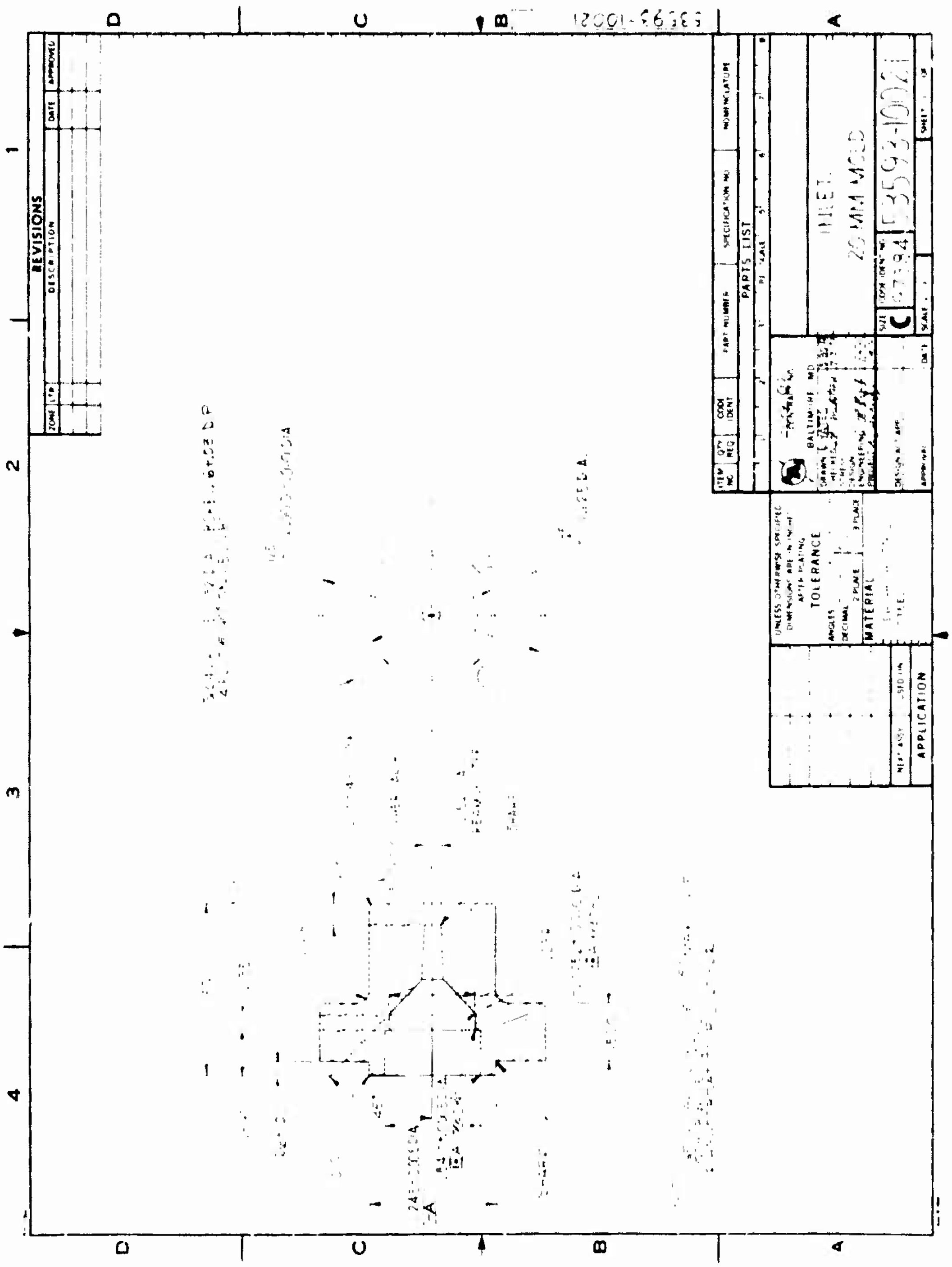
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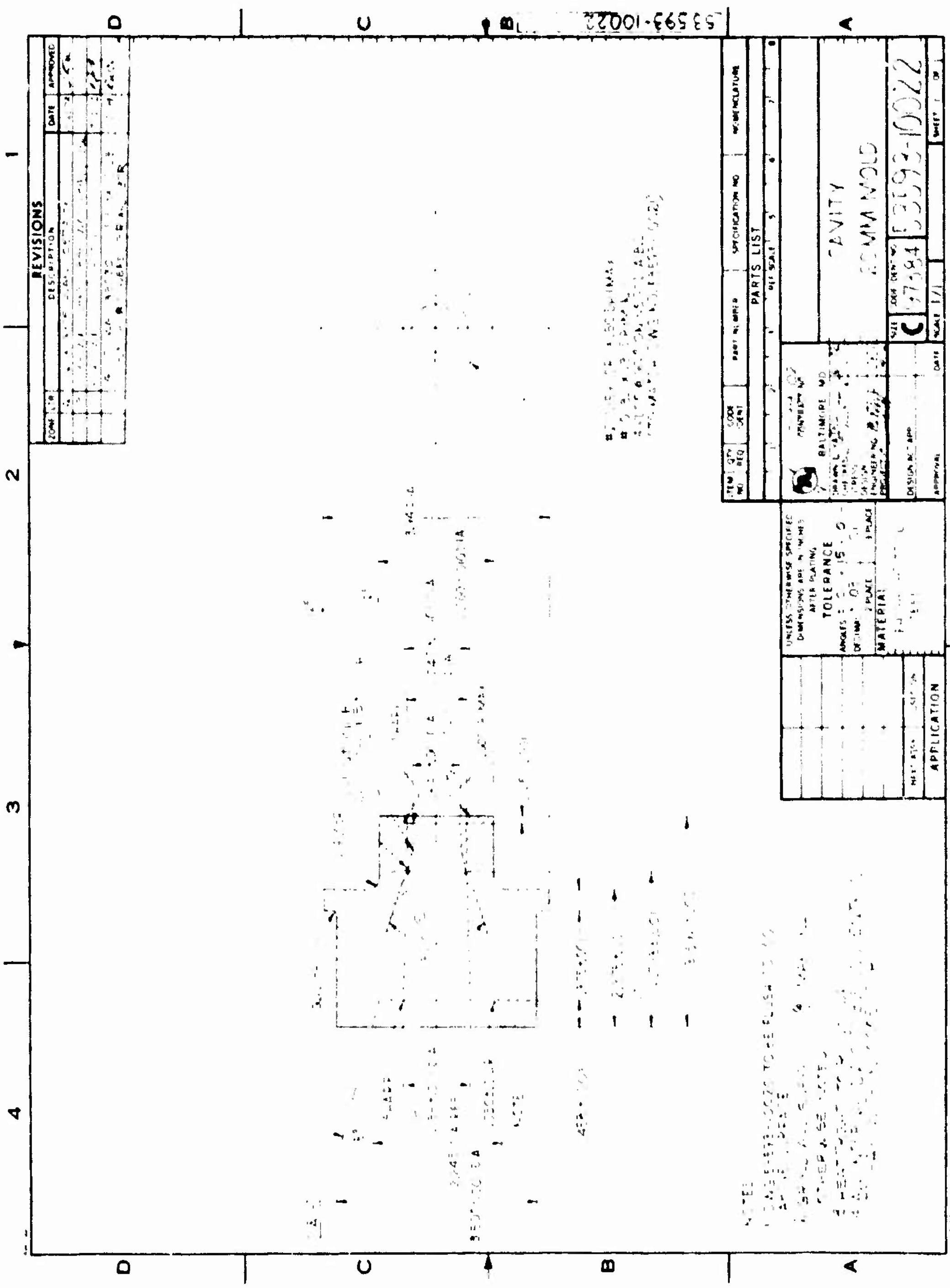
SHEET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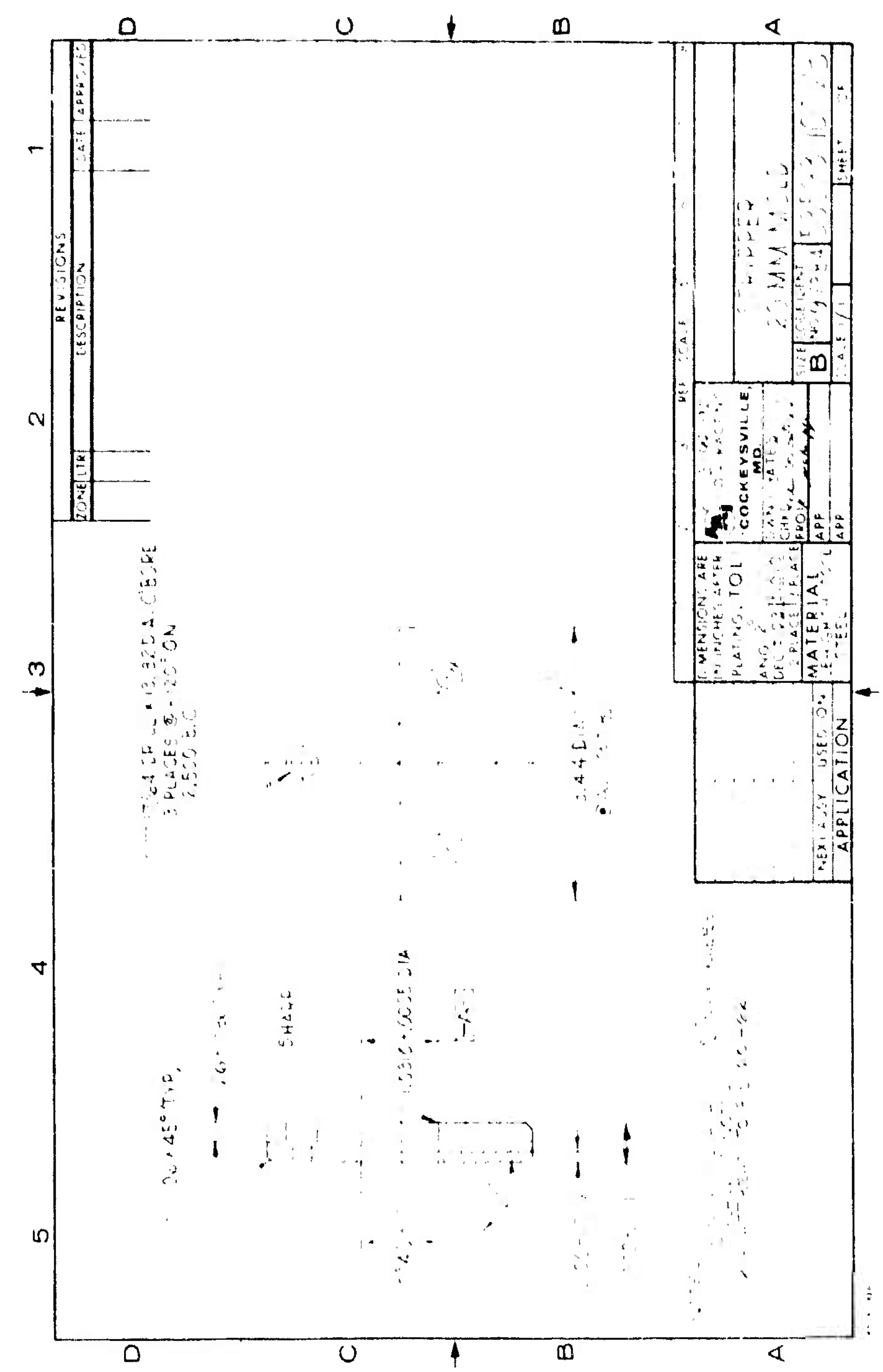

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MATERIAL
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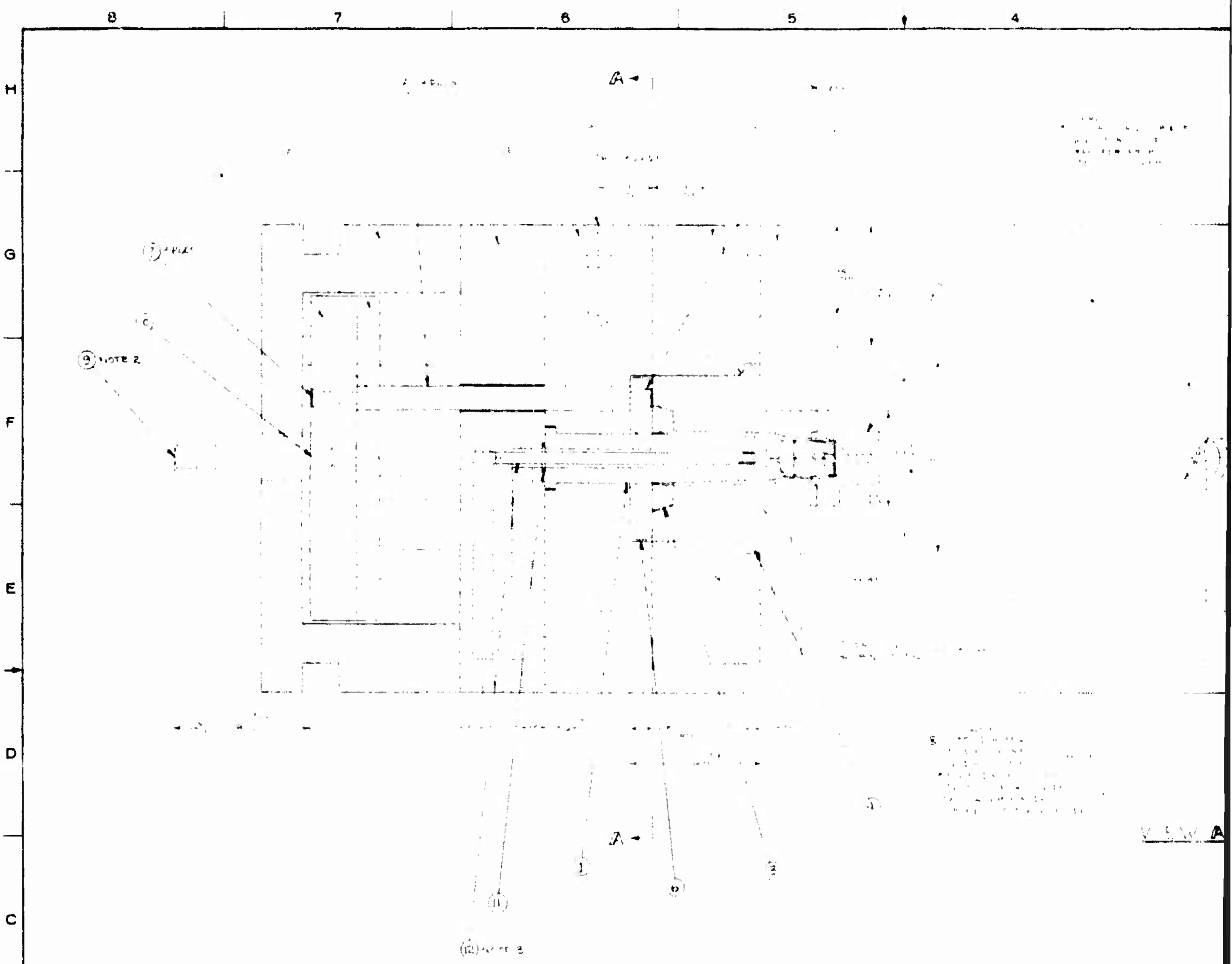


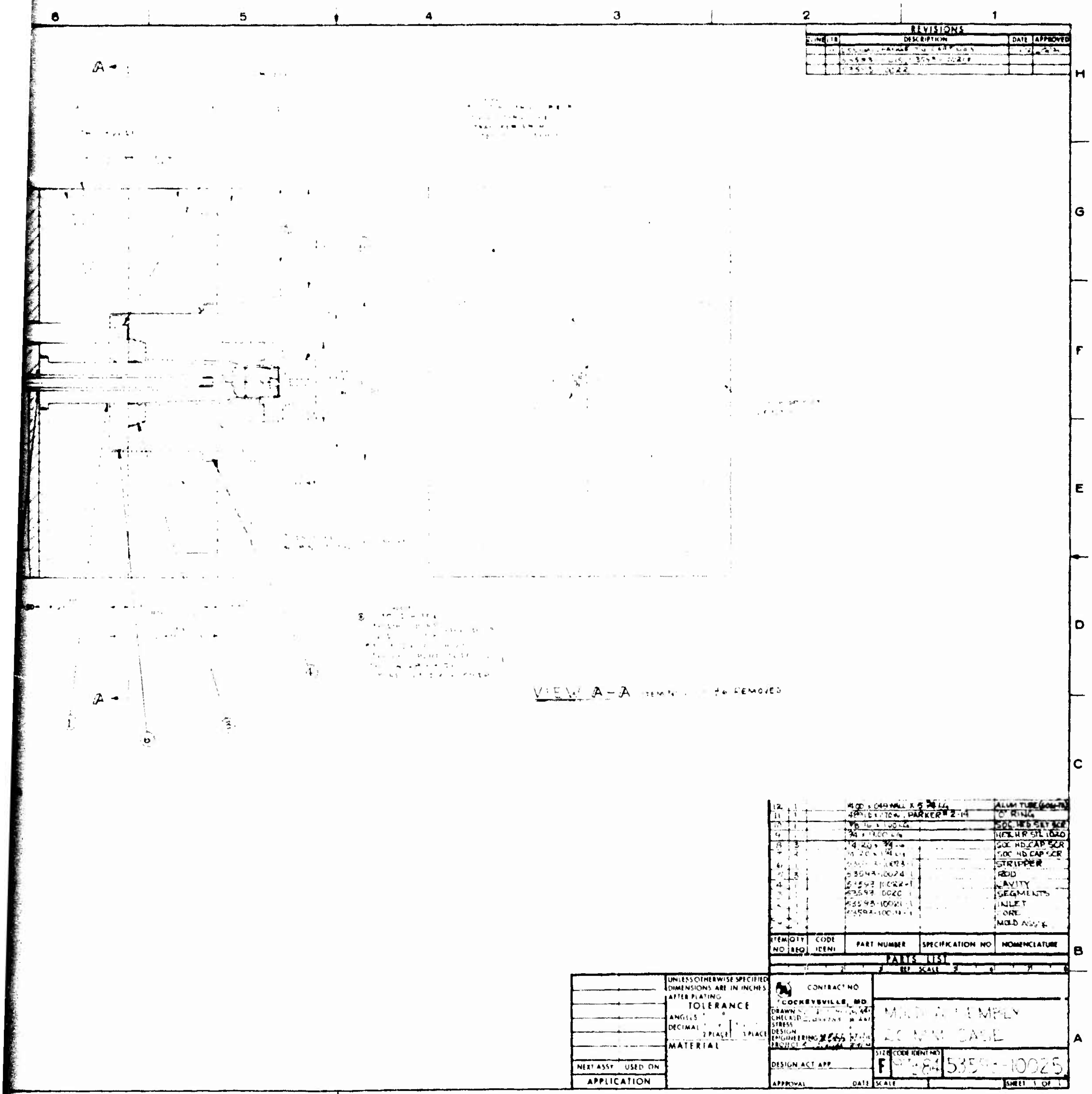
NOTES:

1. D-M-E ... MOLD BASE
9 7/8 × 8.00 × ... (253 LBS)
CAT # 1OBA 23 23P STL
D = 2.990, ... C = 7.92 R = 1/2
SPECIAL: OMIT SPRUE ... HOLE

2. TAP THRU MOLD PART 1&2, TAP ITEM NO. ... DEEP
JAM FIT ITEM NO. 9

3. 1/4-28 THREAD 1 END ITEM NO. 2

4. CONCENTRIC WITHIN .00 T.I.R.



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DDC	2
CINCUSAFE/DMW	1
CINCUSAFE/OA	1
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USN Wpns Ctr (Code 407)	1
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BRL (AMXBR-TBW)	
SMUFA-J7400	1
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13. ABSTRACT

The goals of this program were to arrive at a final design for the 20mm plastic/aluminum cartridge case by: (1) studying and eliminating, if possible, the case cracking problems encountered during temperature extreme firings; (2) improving case resistance to rough handling; and (3) establishing molding process parameters for high volume production. The basic case consists of a plastic body joined mechanically to an aluminum base forming a composite assembly. The existing plastic/aluminum case design was used as a basis, and modifications were made to it as judged necessary. Each modification was followed by test firing to verify and record any changes in performance and case integrity. Test firings were performed with a Mann barrel and with the M61 automatic gun firing at a rate of 4,300 rounds per minute. General results were that temperature extreme firings continued to present problems relating to case integrity. Numerous case modifications with accompanying firing data have served to isolate various failure modes and have led to a better understanding of certain failure occurrences. Further development will be necessary to apply the accumulated knowledge to reduce and subsequently eliminate all case failures. During this program, molding process parameters for high volume production as well as a production mold design have been established. A complete drawing package for the production mold was prepared and is included as Appendix II to this report. In addition, an alternate method of assembling the plastic body and aluminum base was investigated and proven feasible by firing tests. This method consisted of joining the components with a unique bonding process in place of the expensive mechanical joint previously employed.

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14 KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Plastic/Aluminum Cartridge Case						
M61 Cannon						
20mm Cartridge Case						
Type 12 Nylon						

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